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氣象對臺灣一、二期稻作農藝性狀影響之研究[1]

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摘要：利用全省7個地區，5 個品種之 22 套水稻長期區域試驗資料來分析氣象因子對農藝性狀之影響。所考慮之氣象因子有抽穗前45天及抽穗後 30 天之平均氣溫及平均日照時數，農藝性狀有生長日數（由移植到抽穗日數）、成熟日數（由抽穗到成熟日數）、株高、穗數及產量等。因子分析的結果發現氣象因子影響農藝性狀的方式及程度因地區、品種和期作而互異，期作間之差異與氣象因子的關係亦隨地區、品種而有所不同。此種現象不僅是由於品種本身遺傳的機制對氣象變化反應的不同，亦由於存在有遺傳與環境的交感作用。正典相關分析的結果顯示 4 氣象因子與5個農藝性狀的相關性以臺中及屏東地區爲最大，對品種而言則臺南 5 號之相關性最高。本研究認爲一、二期作產量提高的關鍵在於如何由育種上及栽培上去盡量利用氣溫及日照這二大天然資源。

臺灣水稻產量第二期作較第一期作低產爲衆所週知之事實，尤以秈稻之低產情形較稉稻爲嚴重，二期作秈稉稻之產量分別爲一期作之 75 和 80 %左右。第二期作低產原因錯綜複雜，有關之研究報告亦甚多，國科會於民國 68 年所出版之『臺灣二期作稻低產原因及其解決方法研討會專集』一書曾分別由環境因子、植物生理、土壤因子及病蟲害等方面來研究低產之原因，對各種可能之影響因素皆有詳盡的探討，爲至目前爲止對二期稻作低產原因討論最爲詳盡的專書。二期作低產之原因雖然很多，但歸納起來皆或多或少與氣象因子有關（黃，1979）。此源於兩期稻作生長環境的不同主要在於氣象因子的差異（鄔等，1975），由於氣象因子的差異再影響到植物生理、土壤因子和病蟲害等方面，當然氣象因子同時亦影響第一期稻作的產量。因此，氣象因子的不同實爲一、二期作產量差異最根本的原因，所以要提高二期作產量，首先必需明瞭氣象因子對臺灣一、二期稻作產量構成要素及產量的影響。本試驗之目的即針對此一問題探究氣象因子如溫度、日照等對本省第一、二期作稻產量及農藝性狀之影響，並探討氣象因子對不同品種在不同地區之影響方式是否一致。此類資料不僅可作栽培上的對策，同時可供將來水稻育種的參考。

材料與方法

欲探討氣象因子對臺灣一、二期稻作產量構成要素及產量的影響時，氣象及農藝資料愈多愈久則所得之結論自愈可靠，但此等氣象及農藝資料必需能互相配合。本文由於需用到長期的氣象及農藝特性紀錄，故利用農試所所保存的歷年稉稻區域試驗資料，並配合中央氣象局發行的農業氣象旬報，來探討兩期作間氣象因子的變化對產量差異的影響。資料經整理後共有 22 套可供分析，今依地區、品種及年數示於表一。供分析用之農藝性狀計有生育日數（由移植至抽穗日數）、成熟日數（由抽穗至成

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1. 臺灣省農業試驗所 研究報告 第 989 號。本計畫承行政院農業發展委員會補助，謹致謝忱。
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熟日數）、株高、穗數及產量等5項，氣象資料計有抽穗前 45 天及抽穗後 30 天之平均氣溫、最高氣溫、最低氣溫、降水量及日照時數等 10 項。採抽穗前 45 天及抽穗後 30 天之氣象資料的原因，在於前者包括整個幼穗分化過程，而後者則包括整個穀粒充實及成熟過程，此期間對產量之影響最大之故。

分析方法首先以原始資料依地點別、品種別及期作別等進行相關分析、因子分析（factor analysis）及轉軸分析（varimax rotation），並計算農藝性狀及氣象因子之正典相關（canonical correlation）係數；次按地點別、品種別等計算相同年度內兩期作資料所有農藝性狀及氣象因素之差異，並以此差異進行上述各項分析。由此等分析，吾人可以探討各品種在不同地點、不同期作下生長時氣象因子對農藝性狀的影響方式及程度，並進而決定影響產量的直接及間接因素，同時可尋找同品種、同地點在不同期作下生長時影響農藝性狀差異的氣象因子。

結果與討論

一、不同地點、品種及期作之相關及因子分析

由初步之相關分析發現氣象因子之最高氣溫、最低氣溫及降水量等對株高、穗數及產量之影響極小，此可能因最高及最低氣溫之持續時間很短而不致影響水稻之生長，至於降水量則因臺灣之灌溉設施良好，已不再成爲影響水稻產量之重要因素。爲提高因子分析及轉軸分析之有效性（efficiency）

表 1. 資料之地區、品種及使用年數

Table 1. Region, variety and years of data

地區 Region	品種 Variety	期作 Crop	使用年數 Years	兩期作可配合年數 Years which two crops can match
臺北 Taipei	臺中65號 Taichung 65	1 2	26 25	25
新竹 Hsinchu	臺中65號 Taichung 65	1 2	22 21	21
臺中 Taichung	臺中65號 Taichung 65	1 2	14 13	13
臺中 Taichung	臺南5號 Tainan 5	1 2	12 12	11
屏東 Pingtung	高雄27號 Kaohsiung 27	1 2	12 11	11
屏東 Pingtung	臺南5號 Tainan 5	1 2	10 11	9
屏東 Pingtung	嘉農242號 Chianung 242	1 2	14 13	11
花蓮 Hualien	嘉南8號 Chianan 8	1 2	20 19	19
臺東 Taitung	嘉南8號 Chianan 8	1 2	26 25	25
羅東 Lotung	臺中65號 Taichung 65	1 2	14 13	13
羅東 Lotung	臺南5號 Tainan 5	1 2	10 11	9

，所以決定去除這些變數，僅以①生育日數、②成熟日數、③株高、④穗數、⑤產量、⑥抽穗前 45 天之平均氣溫、⑦抽穗前 45 天之平均日照時數、⑧抽穗後 30 天之平均氣溫及⑨抽穗後 30 天之平

均日照時數等 9 個變數進行所有分析。22 套資料之 5 個農藝性狀及 4 個氣象因子分析及轉軸後之因子結構 (factor pattern) 示於表二至表八。不同品種、不同地區、不同期作的因子結構亦不同，換言之，各品種在不同地區、不同期作下，受氣象因子之影響程度及方式也不同。表二至表八僅列出因子分析後之特性根 (eigenvalue) 顯著大於 1 的因子 (factor)，因本文以各變數之標準化值來進行因子分析，故特性根小於或接近 1 的因子其解釋變異的能力反較原來的任一變數爲小，故予忽略。表二至表八亦僅列出因子負荷量 (factor loading) 之絕對植大於 0.4 者，因子負荷量可解釋爲變數 (variable) 及因子 (factor) 之相關係數，此相關係數之絕對值若小於 0.4 者，則無多大實際意義可言 (Harman, 1967)，故爲簡要解釋因子結構起見亦予忽略。茲將不同地區、不同品種之產量因子結構分析結果說明如下：

(一) 臺北地區—臺中 65 號 (表 2)：

表 2. 臺北地區，臺中 65 號的產量因子結構

Table 2. Factor pattern of rice yield for Taichung 65 in Taipei region

時期 Stage	項目 Item	一期作 1st crop 因子 factor 1	2	3	二期作 2nd crop 因子 factor 1	2	3	期作差異 Inter-crop difference 因子 factor 1	2	3
	生育日數 Days of growing		.82		.80			.64		
	成熟日數 Days of maturing		-.61		-.73			-.89		
	株高 Plant height	.71					.76			.58
	穗數 No. of panicle	.84			.59	.46			-.53	
	產量 Yield	.68			.84			.85		
抽穗前 45 天 45 days before heading	氣溫 Air temperature	.54			-.49	.67			-.41	.67
	日照 Sunshine hours		-.80			.52	-.61		-.85	
抽穗後 30 天 30 days after heading	氣溫 Air temperature			.89		.84				.80
	日照 Sunshine hours			.95			-.77		.54	

1.一期作之第 1 因子爲抽穗前 45 天之氣溫與株高、穗數及產量之關係，顯示此時期之高溫可使株高和穗數增加因而使產量增加；第 2 因子爲抽穗前 45 天之日照與生育日數和成熟日數的關係，顯示此時期之日照愈多，雖可縮短生育日數，但反使成熟日數延長；第 3 因子則爲抽穗後 30 天之氣溫及日照的關係，但此時期之氣溫及日照對 5 個農藝性狀的變化無甚直接影響。

2.二期作之第 1 因子很明顯的表示抽穗前 45 天之氣溫對穗數及產量的影響，顯示此時期之高溫導致穗數及產量的減少，並使生育日數減短和成熟日數增長；第 2 因子爲穗數與氣溫及日照之一般關係，可看出抽穗後 30 天之高溫可增加穗數；第 3 因子爲日照與株高的關係，亦即短日照可使株高增長。

3.期作間差異之第 1 因子爲農藝性狀之因子，顯示產量之差異主由生育日數之差異而來，並非穗數之差異所致；第 2 因子爲穗數及氣象因子之關係，穗數差異主由抽穗前 45 天之氣溫及日照差異所引起，但日照之差異較氣溫之差異爲顯著；第 3 因子爲株高與氣溫之關係，顯示株高之差異主要由於氣溫之差異所引起，尤以抽穗後 30 天之氣溫差異爲然。

(二) 新竹地區—臺中 65 號 (表 3)：

表 3. 新竹地區，臺中 65 號的產量因子結構

Table 3. Factor pattern of rice yield for Taichung 65 in Hsinchu region

時期 Stage	項目 Item	一期作 1st crop 因子 factor 1	2	3	二期作 2nd crop 因子 factor 1	2	3	期作差異 Inter-crop difference 因子 factor 1	2	3
	生育日數 Days of growing		-.68		.80				-.80	
	成熟日數 Day, of maturing			.71	-.61	.58			.46	
	株高 Plant height	-.89				-.81		-.83		
	穗數 No. of panicle	-.82						-.82		
	產量 Yield	-.81				-.84		-.90		
抽穗前 45 天 45 days before heading	氣溫 Air temperature		.58	.41	-.81				.50	-.60
	日照 Sunshine hours		.90				.78			-.89
抽穗後 30 天 30 days after heading	氣溫 Air temperature			.44	-.56	-.65			.72	
	日照 Sunshine hours			-.76			.77			-.53

1.一期作之第 1 因子主受株高、穗數及產量所影響，顯示氣溫及日照並不直接影響到 3 個性狀，產量之高低主受株高大小及穗數多少的影響。第 2 因子爲抽穗前 45 天之氣溫、日照和生育日數間的關係，此時之高氣溫和多日照會縮短生育日數。第 3 因子則明顯地表出抽穗後 30 天之日照與成熟日數的關係，抽穗後 30 天之日照愈多，成熟所需日數則愈短。

2.二期作之第 1 因子爲氣溫與生育及成熟日數之關係，抽穗前 45 天之高溫雖可縮短生育日數，但却使成熟日數延長。第 2 因子爲抽穗後 30 天之氣溫與產量、株高及成熟日數之關係，此時之氣溫愈高，不但使成熟日數減少，且使株高和產量增加。第 3 因子主由日照時數所決定，日照時數雖對農藝性狀無直接影響，但可能影響氣溫因而間接再影響到農藝性狀。

3.期作間差異之第 1 因子爲農藝性狀之因子，可看出產量之差異主要是由於穗數及株高差異而來，而不在於生育或成熟日數的差異，此現象與此品種在臺北地區的表現不同。第 2 因子爲氣溫與生育及成熟日數的關係，高溫雖減少生育日數，但却使成熟日數增長。第 3 因子顯示日照差異對農藝性狀之差異無甚直接影響。

（三）臺中地區

1.臺中 65 號（表4）：

（1）一期作之第 1 因子爲抽穗前 45 天之氣溫及日照與株高及穗數間的關係，此時之高溫多日照可增高植株及增多穗數，因而使產量增加。第 2 因子爲產量與生育及成熟日數的關係，顯示生育期及成熟期愈長則產量愈高。第 3 因子爲抽穗後 30 天之氣溫和日照與產量的關係，此時之高溫多日照雖有增加產量之趨勢，但效果不大明顯。

（2）二期作之第 1 因子顯示產量、生育日數及株高間之關係、生育日數及株高的增加可提高產量，而抽穗後 30 天的多日照反而延長成熟日數。第 2 因子爲抽穗後 30 天之氣溫與穗數的關係，此時之氣溫愈高，穗數反而減少。第 3 因子主由抽穗前 45 天之氣溫及日照所決定，顯示此時之氣溫和日照與 5 個農藝性狀無甚直接明顯的關係。由臺中 65 號在臺中地區的表現看來，一期作時抽穗前 45 天之氣溫及日照影響產量及農藝性狀；二期作時則爲抽穗後 30 天之氣溫及日照，情形正好相反。

表 4. 臺中地區，臺中 65 號和臺南 5 號的產量因子結構

Table 4. Factor pattern of rice yield for Taichung 65 and Tainan 5 in Taichung region

時期 Stage	項目 Item	Taichung 65									Tainan 5								
		一期作 1st crop			二期作 2nd crop			期作差異 Inter-crop difference			一期作 1st crop			二期作 2nd crop			期作差異 Inter-crop difference		
		因子 factor			因子 factor			因子 factor			因子 factor			因子 factor			因子 factor		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	生育日數 Days of growing		-.87		.61	-.50		.87			.58		.65		.82			-.67	.66
	成熟日數 Days of maturing		-.68		-.87				.70		-.91					.83	.54		-.80
	株高 Plant height	.81			.84			.50	-.72	.44	.41			-.72			.80		
	穗數 No. of panicle	.88				.85				.79		.79		.66			.63		.53
	產量 Yield		-.74	.43	.91			.86				.79			.49	.81	.73	-.63	
抽穗前前 45 天 45 days before heading	氣溫 Air temperature	.79					-.94	.82				.72	-.44		-.72			.77	
	日照 Sunshine hours	.61					-.81		.56	.44			-.96	.55		-.60		.80	
抽穗後 30 天 30 days after heading	氣溫 Air temperature			.66		-.75		.72			.74	.61		-.58	-.43				.61
	日照 Sunshine hours			.91	-.64					-.75	.95			.71	.45		.87		

（3）期作間差異之第1因子主爲氣溫與生育日數，株高及產量之關係，二期作間氣溫之差異爲影響生育日數、株高及產量差異之最大原因。第2因子爲抽穗前 45 天之日照與成熟日數及株高之關係，此時之日照差異愈大，則成熟日數之差異亦愈大，但株高之差異則愈小。第3因子爲抽穗後 30 天之日照與穗數的關係，此時之日照差異愈大，穗數之差異反而愈小。

2.臺南5號（表4）：

（1）一期作之第1因子爲抽穗後 30 天之氣溫及日照與成熟日數的關係，此時之高溫多日照可縮短成熟日數。第2因子爲氣溫與穗數及產量的關係，可能是高溫增加穗數因而使產量增加。第3因子爲抽穗前 45 天之日照與生育日數的關係，此時之多日照可縮短生育日數。

（2）二期作之第1因子顯示日照與穗數及株高與溫度之關係，多日照可使穗數增加，而抽穗後 30 天之高溫促使植株增高。第 2 因子主爲抽穗前 45 天之氣溫及生育日數之關係，此時之高溫可縮短生育日數。第3因子爲抽穗前 45 天之日照與成熟日數及產量之關係，可能是此時期之短日照縮短生育日數而延長了成熟日數因而使產量增加。

（3）期作間差異之第1因子明顯地表示抽穗後 30 天之日照差異影響成熟日數、株高、穗數及產量之差異。第2因子爲抽穗前 45 天之氣溫及日照與生育日數的關係，此時之氣溫及日照差異影響到生育日數的差異，當然影響到產量的差異。第3因子主爲抽穗後 30 天的氣溫與成熟日數的關係，此時之氣溫差異愈大，成熟日數之差異愈小。

（四）屏東地區：

1.高雄 27 號（表5）

（1）一期作之第1因子顯示生育日數長及抽穗後 30 天之多日照可提高穗數及產量。第2因子爲抽穗前 45 天之日照與穗數的關係，此時之多日照反而使穗數減少。第3因子顯示氣象因子與農藝性狀及產量間無直接關係，即高雄 27 號在屏東地區之第一期作，日照對其農藝性狀及產量的影響較氣溫爲大且直接。

（2）二期作之第1因子爲抽穗前 45 天之日照與生育及成熟日數的關係，此時之多日照雖可縮短生育日數，但却延長成熟日數。第2因子爲抽穗前 45 天之氣溫與抽穗後 30 天之日照與穗數的關係，顯示生育初期的高溫與生育後期的多日照可使穗數增加，尤以生育後期之多日照效果更顯著。第3因子爲抽穗後30天之氣溫與株高及產量的關係，此時之氣溫高不但使株高增加，同時可提高產量。

（3）期作間差異之第1因子主要爲抽穗後 30 天之氣溫及日照與穗數及產量之關係，此時之氣象差異愈大，穗數及產量之差異愈大，可能是氣象差異首先影響到成熟日數之差異，再影響到穗數及產量的差異。第2因子爲抽穗前 45 天之日照與生育日數之關係，此時之日照差異愈小，生育日數之差異反而愈大。第3因子爲抽穗前 45 天之氣溫與株高之關係，顯示一、二期作株高之差異主要受生育初期氣溫差異的影響。

2.臺南5號（表5）

（1）一期作之第1因子主要爲抽穗前 45 天之氣溫及日照與株高、穗數和產量的關係，此時期之高溫及多日照不論對株高、穗數或產量皆有正的效果，可能是高溫及多日照使植株生長良好，穗數增多，因而產量增加。第2因子主要爲氣溫與生育及成熟日數的關係，顯示生長初期之高溫雖縮短生育日數，但生長後期之高溫却反而延長成熟日數。第3因子主要爲抽穗後 30 天之日照與株高的關係，此時之多日照促使株高增加。

（2）二期作之第1因子主要爲生育日數與成熟日數的關係，顯示生育日數的縮減要以成熟日數的延長作代價。第2因子爲氣象因子間的關係。第3因子雖表示抽穗前 45 天之高氣溫及多日照對穗數及產量有增加的效果，但影響並不明顯。第2期作臺南5號在屏東地區之因子結構顯示氣象因子對農藝性狀之影響並不明顯，此或許是因這套資料年數較少，結論有待進一步之證實。

（3）期作間差異之第1因子爲抽穗前 45 天之氣溫、日照及抽穗後 30 天之氣溫與株高及穗數

表 5. 屏東地區，高雄 27 號、臺南 5 號和嘉農 242 號之產量因子結構

Table 5. Factor pattern of rice yield for Kaohsiung 27. Tainan 5, and Chianung 242 in Pingtung region

時期 Stage	項目 Item	Kaohsiung 27									Tainan 5									Chianung 242								
		一期作 1st crop 因子 factor			二期作 2nd crop 因子 factor			期作差異 Inter-crop difference 因子 factor			一期作 1st crop 因子 factor			二期作 2nd crop 因子 factor			期作差異 Inter-crop difference 因子 factor			一期作 1st crop 因子 factor			二期作 2nd crop 因子 factor			期作差異 Inter-crop difference 因子 factor		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	生育日數 Days of growing	.88			.83				-.60			.83		.92					-.95		.75		.84			.52	-.52	
	成熟日數 Days of maturing		.71		-.87			.69				-.84		-.85			-.42		.52	.80			-.57	.70			.81	
	株高 Plant height	.63				.52	.77			.90	-.68		.58	.79			.91				.80			.52	.67	.75		
	穗數 No. of panicle	.63	-.63			-.80		.67			-.84			.41		-.79	.78			.63		-.66			.86	.81		
	產量 Yield	.80					.81	.73			-.77					-.92		.76	-.58	.42	.77		-.75			.83		
抽穗前前45天 45 days before heading	氣溫 Air temperature			.91		-.67				.66	-.77	-.55			-.81	-.44	.83	.41				.87		-.53	.69			-.80
	日照 Sunshine hours		.87		.70				.92		-.80				.85	-.42	.73	.53		.62				-.75				-.84
抽穗後 30 天 30 days after heading	氣溫 Air temperature	.57		.71			.64	.75			-.57	-.58	.45		-.68		.91					.70	-.50				.51	
	日照 Sunshine hours	.86				-.72		.88		-.41			.94		.54			.89		.76			-.54	-.62		.49	.79	

的關係，這些氣象差異愈大，株高及穗數之差異亦愈大。第 2 因子明顯地表示抽穗後 30 天之日照差異爲影響產量差異之最大因素。第 3 因子表示二期作間生育日數之差異愈大，成熟日數之差異愈小，進而使產量差異亦愈大。

3.嘉農 242 號（表5）

（1）一期作之第 1 因子主爲日照與成熟日數及穗數間之關係，顯示多日照有促進分蘖進而增加穗數之效果，同時抽穗後 30 天之多日照亦可延長成熟日數。第 2 因子說明生育日數與株高及產量的關係，生育日數愈長，株高增加，產量亦增加。第 3 因子爲氣溫及穗數的關係，不論是抽穗前 45 天或抽穗後 30 天的高氣溫對穗數均有不利的影響。

（2）二期作之第 1 因子顯示抽穗後 30 天之高氣溫及多日照有使產量增加的趨勢，唯效果並不明顯，另外短生育日數所伴隨而來的長成熟日數亦有提高產量的作用。第 2 因子主要在說明日照與成熟日數及株高的關係，日照少，株高反而增高；另外抽穗後 30 天的日照愈少，成熟所需日數愈長。第 3 因子爲氣溫和株高及穗數的關係，抽穗前 45 天的高溫有使株高增高及穗數增加的作用。

（3）期作間差異之第 1 因子指出二期作間產量的差異主要是由於生育日數、株高及穗數之差異而來，其中尤以穗數差異最爲重要。第 2 因子說明抽穗後 30 天之日照差異是造成成熟日數差異之主因，此時之日照差異愈大，成熟日數之差異亦愈大。第 3 因子顯示抽穗前 45 天的氣溫及日照差異對 5 個農藝性狀之差異無多大直接關係。

（五）花蓮地區—嘉南 8 號（表 6）：

表 6. 花蓮地區，嘉南 8 號的產量因子結構

Table 6. Factor pattern of rice yield for Chianan 8 in Hualien region.

時期 Stage	項目 Item	一期作 1st crop 因子 factor 1	2	3	二期作 2nd crop 因子 factor 1	2	3	期作差異 Inter-crop difference 因子 factor 1	2	3
	生育日數 Days of growing		-.65	.53	.76					.79
	成熟日數 Days of maturing			-.85	-.48	-.62				-.49
	株高 Plant height		.68			-.73	.55		.78	
	穗數 No. of panicle		.86			-.86			.78	-.48
	產量 Yield	-.45	.75			-.73	.46		.85	
抽穗前 45 天 45 days before heading	氣溫 Air temperature	-.86			-.67		.61	.90		
	日照 Sunshine hours	-.74			-.74			.67		
抽穗後 30 天 30 days after heading	氣溫 Air temperature	-.82			-.63		.64	.95		
	日照 Sunshine hours	-.73					.90	.70	.48	

1.一期作之第 1 因子指出抽穗前 45 天及抽穗後 30 天的氣溫及日照雖與產量有關係，但效果不大明顯，其原因可能是氣象因子先影響到其他農藝性狀，再由其他農藝性狀影響到產量。第 2 因子顯示產量與生育日數、株高及穗數的關係，短生育日數所引起的長成熟日數及高植株，多穗數，因而促使產量增加。第 3 因子可用來支持對第 2 因子的解釋，即生育日數的縮短會使成熟日數延長。

2.二期作之第 1 因子爲氣象因子與生育及成熟日數的關係，抽穗前 45 天的高溫及多日照明顯地

可縮短生育日數；而抽穗後 30 天的高溫反而延長成熟日數，但效果並不明顯。第 2 因子說明產量與成熟日數、株高及穗數的關係，可看出成熟日數的延長，植株的增高及穗數的增多有提高產量的作用，尤以穗數與產量的關係最大。第 3 因子顯示氣溫及抽穗後 30 天的日照與株高及產量的關係，高氣溫及成熟期的多日照可使植株增高並提高產量，唯氣溫與日照對產量提高的效果是間接的，此由第 2 因子之結構可看出。

3. 期作間差異的因子結構顯示二期作間氣象因子的差異並不直接影響到 5 個農藝性狀的差異，雖然抽穗後 30 天的日照差異可用來解釋株高、穗數及產量的差異，但解釋能力不大。由因子結構中可看出產量的差異主要是由株高及穗數之差異而來；而穗數之差異又與生育及成熟日數之差異有關，若生育日數之差異愈大，成熟日數差異愈小，則穗數之差異亦愈小。

（六）臺東地區—嘉南 8 號（表 7）

表 7. 臺東地區，嘉南 8 號的產量因子結構

Table 7. Factor pattern of rice yield for Chianan 8 in Taitung region

時期 Stage	項目 Item	一期作 1st crop 因子 factor 1	2	3	二期作 2nd crop 因子 factor 1	2	3	期作差異 Inter-crop difference 因子 factor 1	2	3
	生育日數 Days of growing			.81	.78			.52		
	成熟日數 Days of maturing	-.50		-.50	-.84				-.72	
	株高 Plant height		.47			-.88			.50	.66
	穗數 No. of panicle			.69			-.79			.48
	產量 Yield		.43			-.90				.86
抽穗前 45 天 45 days before heading	氣溫 Air temperature		.78		-.52	.49	-.51		-.68	
	日照 Sunshine hours		.80		-.73				-.71	
抽穗後 30 天 30 days after heading	氣溫 Air temperature	.89					-.72	-.83		
	日照 Sunshine hours	.89					-.54	-.92		

1. 一期作之第 1 因子說明抽穗後 30 天之氣溫和日照與成熟日數的關係，此時之高溫及多日照縮短成熟日數。第 2 因子顯示抽穗前 45 天之氣溫及日照與株高和產量的關係，此時之高溫及多日照有增加株高及產量的作用，唯效果並不十分明顯。第 3 因子表明穗數與生育和成熟日數的關係，較長之生育日數（或短成熟日數）會使穗數增加。

2. 二期作之第 1 因子為抽穗前 45 天之氣溫及日照與生育日數之關係，此時之高溫及多日照雖有縮短生育日數之作用，但却以增加成熟日數為代價。第 2 因子為抽穗前 45 天之氣溫、株高及產量的關係，抽穗前 45 天在高溫環境下不利於株高及產量。第 3 因子主要為抽穗後 30 天之氣溫與穗數的關係，抽穗後 30 天之高溫對穗數有利，自然使產量提高。

3. 期作間差異的第 1 因子應解釋為二期作間抽穗後 30 天之氣溫及日照差異直接影響到成熟日數的差異，再間接影響到生育日數的差異。第 2 因子與第 1 因子類似，亦應解釋為抽穗前 45 天之氣溫及日照差異直接影響到生育日數的差異，再間接影響到成熟日數的差異。第 3 因子明顯地表示產量之差異主由株高及穗數差異而來，可能是氣象差異影響到株高及穗數的差異，再影響到產量的差異。

表 8. 羅東地區，臺中 65 號和臺南 5 號之產量因子結構

Table 8. Factor pattern of rice yield for Taichung 65 and Tainan 5 in Lotung region

時期 Stage	項目 Item	Taichung 65									Tainan 5								
		一期作 1st crop 因子 factor			二期作 2nd crop 因子 factor			期作差異 Inter-crop difference 因子 factor			一期作 1st crop 因子 factor			二期作 2nd crop 因子 factor			期作差異 Inter-crop difference 因子 factor		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	生育日數 Days of growing		.85		.59	-.46	.44	-.76					-.42		-.87				-.82
	成熟日數 Days of maturing	-.79				.87		.84			-.75		.43		.46	.64		-.86	
	株高 Plant height		-.68		.69			-.66					-.74	-.88				.81	
	穗數 No. of panicle		.85				-.97		-.49	-.75			.77	-.83					.76
	產量 Yield	-.48	-.55	-.41	.55	-.69						-.84		-.77			-.72		.55
抽穗前 45 天 45 days before heading	氣溫 Air temperature			.93	-.80				.81			-.92			.90		-.54	-.74	
	日照 Sunshine hours			.87	-.72				.93		-.57	-.61		-.41		.60		-.58	.68
抽穗 30 前天 30 days after heading	氣溫 Air temperature	-.86			-.90			.61			.79	-.43			.54	-.71	-.93		
	日照 Sunshine hours	-.85			-.45	-.64				-.85	.86					-.74	-.88		

（七）羅東地區

1.臺中 65 號（表8）

（1）一期作之第1因子顯示抽穗後 30 天之氣溫及日照與成熟日數及產量的關係，此時之高溫及多日照反而延長成熟日數，並使產量增加。第2因子指出生育日數及穗數的增多非但無法使產量增加，反而減少產量，此時產量之增加要靠較長的成熟日數，而非生育日數。第3因子可看出抽穗前 45 天之氣溫和日照與產量的關係並不十分明顯。

（2）二期作之第1因子代表氣象因子與生育日數、株高及產量的一般關係，二期作全生育期的高溫及多日照雖可縮短生育日數，但株高及產量亦隨著降低。第2因子顯示抽穗後 30 天之多日照對縮短成熟日數及提高產產量的效應。第3因子可看出生育日數與穗數之間的關係，顯示生育日數的增長可使穗數減少，但其關係並不十分明顯。

（3）期作間差異的第1因子表示抽穗後 30 天之氣溫差異爲成熟日數差異的主因，且此時氣溫之差異愈大，株高之差異反而愈小。第2因子明顯表出抽穗前 45 天之氣溫及日照差異是造成穗數差異的主因，此時期之氣溫及日照差異愈大，穗數之差異反而愈小。第3因子爲抽穗後 30 天之日照差異對穗數的影響，此時之日照差異愈大，穗數之差異亦愈大，且關係十分明顯。

2.臺南5號（表8）

（1）一期作之第1因子爲抽穗後 30 天之氣溫及日照與成熟日數之關係，與其他地區，其他品種之表現類似，此時之高溫與多日照可縮短生育日數。第2因子爲抽穗前 45 天之氣溫及日照與產量的關係，此時之氣溫及日照對產量有絕對的影響，高溫及多日照可使產量提高。第3因子爲株高與穗數的關係，株高愈矮，穗數愈多。

（2）二期作之第1因子主要說明產量、穗數及株高的關係，亦即產量的高低與株高的大小及穗數的多寡有密切的關係。第2因子顯示抽穗前 45 天的高溫雖使生育日數縮短，但此效果却延長了成熟日數。第3因子爲抽穗後 30 天之氣溫及日照與成熟日數的關係，此時的高溫及多日照縮短成熟所需日數。

（3）期作間差異之第1因子明顯指出二期作間產量的差異主要是由於抽穗後 30 天之氣溫及日照所決定，此時期之氣溫差異愈大，日照差異愈多，產量之差異亦愈大。第2因子指出抽穗前 45 天之氣溫及日照差異愈大，生育日數之差異雖愈小，但反使成熟日數之差異增大，同時株高之差異亦變小。第3因子可用來補充說明第2因子，即抽穗前 45 天之日照差異愈大，生育日數之差異愈小，但穗數及產量之差異却愈大，穗數差異與日照差異之關係尤其明顯。

由以上結果觀之，不同地區或不同品種，不論是一期作、二期作或期作間之差異，其因子結構都不盡相同，可知氣象因子對農藝性狀的影響方式及程度因地區或品種之不同而異，此非但是由於品種本身遺傳因子的差異，尙有遺傳及環境的交感作用（genetic-environment interaction）的存在。在本研究中，臺北、新竹、臺中及羅東4地的氣象因子對臺中 65 號的影響程度及方式即大不相同；同樣地，臺中、屛東、羅東3地的氣象因子對臺南5號的影響方式及程度也互異，反過來說，相同地區的不同品種如臺中地區的臺中 65 號和臺南5號及屛東地區的高雄 27 號、臺南5號和嘉農 242 號等所受到的氣象影響也不同。雖然氣象因子的差異祇是環境差異的一部份，但如前所述，氣象因子的差異可影響到植物生理、土壤因子及病蟲等方面，所以可視爲造成環境差異最重要的因素。品種在遺傳上的不同，再加上相當程度的遺傳與環境交感作用，使得氣象因子對水稻農藝性狀的影響方式及程度亦因地區、品種及期作之不同而互異，很難（甚或不可能）尋出一個通則。因此要談到農業氣象對水稻產量及農藝性狀的影響必須針對某一地區、某一品種之某一期作而言才有實際意義，此即何以一般當地慣用品種（local variety）通常皆有甚高及較穩定產量的原因，因當地品種即是由於較能够適應當地氣候環境而得以被長期保留的緣故。

二、農藝性狀及氣象因子之正典相關分析

農藝性狀及氣象因子的相關性可由正典相關係數（canonical correlation coefficient）看出，正典相關爲兩“組”變數間相關程度的一個指標（Press, 1972）。不同地區、不同品種、不同期作及期作間差異之5個農藝性狀和4個氣象因子的正典相關係數列於表九。表九中之所有正典相關係數皆甚高，顯示氣象因子確實影響到農藝性狀的表現，雖然其影響之方式及程度因地區、品種及期作而有所不同。以地區而言(表9)，臺中及屏東地區氣象因子與農藝性狀之相關性最高，其次爲羅東地區，而臺北、新竹、花蓮及臺東地區的相關性則較小。以品種而言(表9)，臺南5號（0.98）與氣象因子的相關性最高，亦即其對氣象變化的反應較敏感，高雄 27 號（0.97）及嘉農 242 號（0.93）之相關性次之，而臺中 65 號（0.83）及嘉農8號（0.75）則較小。以期作而言（表9），二期作時氣象因子與農藝性狀之相關性較一期作爲高，此與吾人認爲一、二期作產量差異主要是由氣象因子之差異而引起的假設相符合。雖然由因子分析的結果可看出氣象因子對農藝性狀影響的方式及程度因地點、品種及期作而有所不同，但氣象因子與農藝性狀的相關性不論對地區或對品種而言皆相當穩定，如臺南5號不論在臺中、屏東或羅東，其農藝性狀與氣象因子之相關性皆甚高；再如臺中地區的臺中 65 號、臺南5號及高雄 27 號或羅東地區的臺南 5 號及嘉農 242 號，其農藝性狀與氣象因子的相時性亦甚高。一、二期作產量差異雖有很多原因，但究其根本，生長環境的不同應是造成此種差異的主因，而氣象因子的不同又是造成一、二期作生長環境差異的來源。表九中各地區、各品種在一、二期作下農藝性狀與氣象因子的高相關性爲此種論點的另一證據。

表 9. 氣象因子與農藝性狀之正典相關係數

Table 9. Canonical correlation coefficient between climatic factors and agronomic characters

地區 Region	品種 Variety	一期作 1st crop	二期作 2nd crop	期作差異 Inter-crop difference	平均 Average
臺北 Taipei	臺中 65 號 Taichung 65	.69	.72	.76	.72
新竹 Hsinchu	臺中 65 號 Taichung 65	.86	.82	.78	.82
臺中 Taichung	臺中 65 號 Taichung 65	.78	.97	.98	.91
臺中 Taichung	臺南 5 號 Tainan 5	.98	.95	.99	.97
屏東 Pingtung	高雄 27 號 Kaohsiung 27	.96	.97	.98	.97
屏東 Pingtung	臺南 5 號 Tainan 5	.98	.93	.99	.97
屏東 Pingtung	嘉農 242 號 Chianung 242	.89	.91	.98	.93
花蓮 Hualien	嘉南 8 號 Chianan 8	.69	.86	.89	.81
臺東 Taitung	嘉南 8 號 Chianan 8	.64	.80	.63	.69
羅東 Lotung	臺中 65 號 Taichung 65	.86	.96	.84	.87
羅東 Lotung	臺南 5 號 Tainan 5	.98	.96	.99	.98
平均 Average		.85	.90	.89	

結 論

氣象因子與水稻產量的關係十分複雜，因水稻產量是由其他農藝性狀所決定，亦可說產量是水稻整個生長過程的最後產物，而氣象因子在水稻某一生長過程中的變化對水稻最後產物所造成的影響不易立即衡量決定，尙須視在其他生長過程中氣象因子的變化對水稻生長的影響，生長過程某一階段由

氣象因子所引起的不利影響也許在其他階段反可由氣象因子的作用來獲得補償 (Tanaka, 1976)，而品種與環境交感作用的存在更增加此種複雜性。在諸如人工氣候室 (phytotron) 中嚴密控制環境下所得到的氣象因子（如氣溫、日照等）與產量及農藝性狀之關係尚不足以代表在田間的眞正關係，科學再發達，研究者在實驗室中所能控制的複雜的環境畢竟與實際田間狀況尚有距離。臺灣的一、二期稻作事實上在互不相同的環境下生長，所有努力不論是在栽培上或在育種上也都在求如何儘可能的利用這些環境；施肥可以增加土壤養分，灌溉可以補救降水的不足，其他可資利用的天然資源尚有氣溫及日照，如能善加利用水稻在不同生長過程中與氣溫及日照的關係，並從中得利，則不僅二期作有增產的可能，一期作也有再增產的希望。

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Influence of climate on the yield and agronomic characters of the first and second crop rices in Taiwan[1]

C. Liu, S. C. Hsieh and M. H. Lin[2]

Summary

A total of 22 sets of data including 7 regions and 5 varieties from long-term regional trials were used to study the influence of climatic factors on the agronomic characters of rice. Climatic factors considered were the mean air temperature and the mean sunshine hours 45 days before and 30 days after heading respectively. Agronomic characters studied were the days of growing (days from transplanting to heading), days of maturing (days from heading to maturing), plant height, number of panicles and the yield.

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Results from factor analysis revealed that the pattern and the magnitude of the climatic influence on the agronomic characters (1st crop, 2nd crop or inter-crop difference) differ quite a lot from region to region and from variety to variety. The different response to climatic change due to the genetic mechanism of the varieties themselves is not the only cause attributed to thus phenomenon, there are also evidences indicating the existence of the genetic-environment interaction.

Results from canonical correlation analysis showed that Taichung and Pintong have the highest association between the 4 climatic factors and 5 agronomic characters. As for the variety, Tainan 5 is the most prominent one.

Utilization of temperature and solar radiation to improve the rice yield is suggested and briefly discussed.

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水稻臺農 67 號產量潛能之研究

I. 產量構成要素之表現[1]

郭 益 全[2]

摘要：為檢討水稻臺農67號之產量潛能，本試驗以臺南5號為對照，藉兩品種諸主要性狀之比較，以推定臺農67號高產之決定性狀。經1年兩期作之試驗調查發現：在1期作生育條件下，臺農67號較對照種臺南5號增產 9.1%，其差異已達5%之顯著水準。而其高產之癥結似因臺農67號之穗數較對照種臺南5號者為多，致單株之生物產量增加而穀產量增加，而與兩品種之收穫指數無關。而在2期作環境下，臺農67號豐產之癥結如一期作者，亦奠基於該品種之多穗數。惟本期作下，臺農67號雖較對照種臺南5號增產 4.2%，但兩品種單株穀產量之差異並未具統計上之意義。

水稻臺農 67 號是臺灣省農業試驗所由（臺中 187 號×臺農 61 號）×臺農 61 號於民國 62 年一期作選出，而於 67 年二期作正式命名推廣之稉稻新品種[1,2]。因本品種不僅產量很高，且有耐粗放栽培及植株稍矮莖稈强硬不倒伏適機械收穫等優點。故廣受各地農民之歡迎。據農林廳之統計[4]，68 年二期作臺農 67 號全省之栽培面積已超過 13.3 萬公頃，顯示臺農 67 號雖尚存有若干缺點，但已被公認為頗具高產潛能之稉稻新品種。

而作物產量之決定，以農藝觀點言，產量乃由各該作物主要產量構成要素所綜合累積而成。而就生理上言，產量則為作物光合作用淨乾物產量之蓄積，亦即作物具經濟價值之產量（economical yield）可由各該作物之生物產量（biological yield）及收穫指數（harvest index）之乘積來決定。為探討此臺農 67 號之高產特性，本研究以全省栽培面積曾超過 21 萬公頃之臺南 5 號[3] 為對照，藉產量有關性狀、生物產量及收穫指數之評估，以探究臺農 67 號高產之特性，俾提供今後稉稻育種選拔之參考。

材料與方法

參試水稻材料除目標品種臺農 67 號外，另以臺南5號為對照。試驗於 69 年1及2期作在本所試驗田進行，生育期間曾加適時之病蟲害防治。肥料用量：硫酸錏，過磷酸鈣及氯化鉀之用量1期作依次為 600，300 及 80 kg/ha；2期作依次為 560，200 及 80 kg/ha。田間設計用駢對逢機排列法，重覆4次。每品種每重覆均插植7行，每行 12 株，單本植。收穫時去首尾及邊行，連根挖回進行調製與調查。調查項目計有各單株之生物產量，經濟產量，收穫指數，株高及產量構成要素。每重覆各性狀之表現是以 50 單株之平均來表示；兩品種各性狀之比較則以駢對 t 法行均值差異顯著性之測驗。

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1. 臺灣省農業試驗所 研究報告 第990號。本文蒙本所農藝系主任謝順景及劉大江博士之斧正，謹表謝忱。

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結果與討論

一、兩品種經濟產量、生物產量及收穫指數之表現

作物之收穫指數有稱轉移係數 (migration coefficient)[16] 者，有稱效率係數 (effectiveness coefficient)[12] 者，均係指具經濟價値的產量與生物產量之比值。然就禾穀類作物而言，具經濟價値的部位通常指穀粒；而生物產量則指地上部藁草與穀粒之總重[7]。研究報告指出：在許多禾穀類作物品種比較試驗中，均發現收穫指數與產量呈正相關[14,15] 而穀產量（經濟產量）與全株乾重（生物產量）間雖具正相關，但相關係數値則甚低。故有人推斷作物栽培品種之產量高低主要依其對光合作用淨乾物產量之分配而定，亦即高產品種並非具有較强之光合能力，而是因爲該品種能將較多之光合產物分配至具有經濟價値之植物體部份[8,9,13]。因此 Nicoporvic[11] 認爲收穫指數就某種角度言，可成爲評估作物生物效率之有效指標。故而，能有效地將植株同化產物轉移至穀粒，而甚少殘積在藁草部份之理想株型，應是育種家所追求之目標。

基此，本研究首先比較參試兩品種之經濟產量、生物產量及收穫指數（表 1 ）期能穫知臺農 67 號高產之特性。觀表 1 可知：在 1 期作之環境條件下，臺 67 號之經濟產量顯著地高於對照種臺南 5 號，其增產値高達 9.1 %。至於生物產量，則臺農 67 號亦顯著地高於其對照種臺南 5 號。惟兩品種之收穫指數則相同。2 期作生育環境下，兩品種 3 性狀之表現雖臺農 67 號均略優於臺南 5 號，但皆未具統計上之意義。然就表 1 之數據全面考慮則似，兩期作下臺農 67 號之高經濟產量乃導因於其較高之生物產量，而與收穫指數者無關。亦即本研究之結果雖異於前人收穫指數可作爲評估該作物生物效率之指標[11] 及穀產量與全株乾重（生物產量）無關[8,9,13] 之推論，但却與梁[5] 在水稻收穫指數方面之研究相同。即經濟產量高者生物產量有較重之趨勢。同時梁[5] 之數據亦顯示本省推廣之優良高產品種（包括臺南 5 號等）的收穫指數均在 45～55 %之間，是所評估 245 水稻品種中收穫指數較高的一羣。且收穫指數高×高之雜交組合中，僅存在基因之累加性作用；其遺傳率又極高；選拔亦甚易奏效[5]。更因目前雜交育種親本之選擇，除特殊抗病蟲種源親本外，槪屬收穫指數較高之品種（系），因此建議，在目前高收穫指數×高收穫指數之育種目標集團下，稉稻育種之選拔，收穫指數似可較爲忽視，而表示各植株光合產物蓄積能力之生物產量應屬吾人須稍加考慮之性狀之一。

表 1. 兩品種經濟產量、生物產量及收穫指數之比較

Table 1. A comparison of economic yield, biological yield and harvest index between Tainung 67 and Tainan 5[a]

Crop seasson	Variety	Economic yield (g/plnat)	Biological yield (g/plant)	Harvest index
1980 I	Tainung 67	29.88 a	55.86 a	0.53 a
	Tainan 5	27.39 b	51.58 b	0.53 a
1980 II	Tainung 67	19.74 a	46.47 a	0.42 a
	Tainan 5	18.94 a	45.64 a	0.41 b

a. Means followed by the same letter are not significantly difference at 5 % level in each crop season.

二、兩品種株高與產量構成要素之表現

表 2 爲參試兩品種各主要性狀在兩期作生育條件下之表現。由表 2 株高項下知，臺農 67 號顯著地矮於其對照種臺南 5 號。此數據配合表 1 兩品種之生物產量及收穫指數的資料可推定：同品種不同

期作時株高似與收穫指數及生物產量有關；但同期作不同品種時，株高與收穫指數及生物產量間並無任何趨勢存在。亦即由本試驗之數據似不能認定株高與收穫指數及生物產量間有相關關係存在。而本研究此等結果恰與 Chang and Li [6] 之株高爲關係收穫指數之一極重要性狀的論證不同；而與梁 [5] 之水稻收穫指數之遺傳與環境效應及其與農藝性狀間之相關的研究完全相符。

再由表 2 就兩品種 4 產量構成要素來比較，數據顯示臺農 67 號是相對多穗數而小穀粒之粳稻品種；臺南 5 號則爲相對大穀粒而少穗數之品種，而本研究有關臺農 67 號與臺南 5 號相比時爲相對多穗數品種之結果，與黃（1979）區域試驗之數據不盡一致 [1] ，推想原因可能爲本研究田間栽培爲單本植，而區域試驗則採 3 — 5 多本植之故。若將兩品種主要產量構成性狀之差異參照表 1 兩品種經濟產量，生物產量及收穫指數等性狀之表現作通盤之考慮，吾人似可推論：臺農 67 號之豐產似奠基於本品種之穗數較對照種臺南 5 號者爲多，致單株之生物產量增加，進而經濟產量增加，而與收穫指數無關。此論定恰可由筆者等從事秈粳異型間雜交後代 F_2 單株穀產量變異性主由穗數來決定之路徑分析結果相印證（尙待發表資料）。

表 2. 兩品種株高及產量構成要素之比較

Table 2. A comparison of plant hight and yield components between Tainung 67 and Tainan 5[a]

Crop searon	Variety	Plant height (cm)	Panicle number per plant	Spikelet number per panicle	% seed setting	1,000 grain weight (g)
1980 I	Tainung 67	103.6 a	11.5 a	114.0 a	94 a	24.16 a
	Tainan 5	117.4 b	9.7 b	107.9 a	94 a	27.44 b
1980 II	Tainung 67	97.4 a	13.4 a	106.5 a	65 a	21.39 a
	Tainan 5	108.9 b	11.9 b	111.6 b	64 b	23.90 b

a. Means followed by the same letted are not significantly difference at 5 % level in each crop season.

總結本研究之結果，吾人似可建議育成豐產粳稻之選拔目標實應著重在生物產量較重及一株穗數較多重點上。而選拔之首要目標在選出生物產量較重且一株穗數較多之選株，而當首要目標滿足後，吾人再從中選取高收穫指數之單株，即可滿足育種家選獲豐產粳稻選系（品種）之目標。

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Studies on yield potential of Tainung 67 rice

1. The performance of yield components[1]

Y. C. Kuo[2]

Summary

The recently released high yielding rice Tainung 67 is currently the most popular variety in Taiwan. In order to evaluate the yield potential of this variety, various yield components, economic yield, biological yield as well as harvest index were studied in comparison with the past high yielding variety Tainan 5.

Tainung 67 yielded 9.1% higher than that of Tainan 5 in the first crop at 5% level of significance. This was found to be due mainly to the larger mumber of panicles which lead to an increase of biological yield in Tainung 67. No difference in harvest index between Tainung 67 and Tainan 5 was observed. In the second crop, Tainung 67 gave 4.2% higher grain yield than Tainan 5; it was found to be due to the similar reason as that observed in the first crop.

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秈稉稻雜交之遺傳育種研究

I. 單株穀產量之路徑係數分析[1]

郭益全 張德梅[2]

摘要：本研究以秈×稉與稉×秈等兩個雜交組合之F_2集團為材料，探討秈稉稻雜交後代產量構成要素對單株穀產量變異之決定程度，結果發現：兩種組合中，單株穀產量與產量構成要素間均呈極顯著之正相關。路徑係數分析結果則顯示兩種組合中，產量構成要素對產量變異決定程度的大小順序並不一致。在秈×稉組合中，對單株穀產量變異最具影響力之性狀為穗數，其次為平均一穗穎花數，再次為結實百分率，終為千粒重；稉×秈組合中，產量構成要素對單株穀產量變異之決定程度的大小則依次分別為結實百分率、穗數、平均一穗穎花數、千粒重。文中曾對此等結果加以討論，並建議育種家從事秈×稉或稉×秈雜交育種時，穗數及平均一穗穎花數為譜系法選拔時之兩個重要選拔指標。

栽培稻 *Oryza sativa* L. 有兩個亞種 (subspecies) 。其一為印度型 (*indica*) ，或稱秈稻 (Sen) ；另一為中國型 (*chinensis*[2], *sinica*[6]) ，或稱稉稻 (Keng) ，或習稱日本型 (*japonica*)。由於傳播途徑及馴化過程之不同，兩亞種間不僅形態、生態、生理及血清反應有異，即對外在生育環境之適應能力也有若干程度之不同[2,6] 咸認秈稻之生長競爭力强 (臺中65號對烏尖)[2]，分蘖力强，耐旱且較抗稻熱病[2,10,14]，米粒蛋白質含量雖較稉稻者略高[2,3,18]，惟食用品質則較不受省民所接受[3]。反之，稉稻則根活力强[13]，耐肥耐寒且較不易罹白葉枯病[2,14]，穀粒容重量較秈稻者重，且飯粒食味濃厚而深受省民歡迎[3]

秈稉兩型稻既各有其優劣點，長久以來學者專家即曾著手進行秈稉稻異型間雜交育種之基礎遺傳研究[2,9,12]，惟因秈稉異型間之雜交有稔實率低下之障礙，諸多學者遂盡力於稔實性障礙方面遺傳機制之研討[17] 而秈稉異型間雜交後代之主要經濟性狀之分離情形及遺傳變異的報告則不多見[2]。

本省稻作年有兩期，栽培品種也有秈稉兩類，然2期作單位面積產量向較1期作減產 20% 左右。其中秈稻2期作減產之幅度尚較稉稻者嚴重[8]。鑒此，黃[7] 建議集兩型合意性狀於一個品種。本所萬所長[11] 更具體指出，將來之育種應朝綜合秈稉稻許多優良特性，育成適合二期作之品種，一方面以稉稻為基礎，維持根活力，耐寒性、耐肥力、優良米質及白葉枯病之抵抗性，而注入秈稻之分蘖性、半矮性抗倒伏及稻熱病之抵抗性，但保持稉稻之型態；另一方面以秈稻為基礎，保持其在高溫下之分蘖特性，半矮性抗倒伏及耐病蟲力，而改善其根系的活力、耐寒性、米質及耐肥力而維持其秈稻的型態。

據此，農試所遺傳研究室仍進行秈×稉及稉×秈之異型間雜交，針對秈稉異型間雜交後代主要產量及米質性狀作系列之探討。本文首先報告兩類 F_2 集團單株穀產量之路徑分析結果，至於主要經

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1. 臺灣省農業試驗所 研究報告 第 991 號。本文承蒙劉 清博士斧正，謹表謝忱。
2. 本所農藝系助理研究員。臺灣省 臺中縣 霧峰鄉。

濟性狀及米質問題之遺傳模式則在另文探討。

材料與方法

供單株穀產量路徑分析之雜交組合計兩個。秈×稉的組合爲嘉農秈11號×臺農 67 號；稉×秈之部分爲臺南5號×臺中在來1號。兩雜交組合之 F_2 集團及其親本皆係1979年二期作之材料。每組合插植 32 行，每行 12 株，單本植。行株距 25×25cm，肥料用量 N：P：K=90：40：60 (kg/ha)。收穫時每組合均去邊行；每行去首尾株。故實際調查數每組合僅中間 300 株。調查性狀計有單株之穗數，平均一穗穎花數，結實百分率，千粒重及穀產量等五個性狀。

遺傳介量之估算計有兩組合五性狀間之表現型相間及遺傳型相關等兩類估值，其公式如下：

$$表現型相關係數(r_P)=\frac{COVxy_{F2}}{\sqrt{Vx_{F2}\ Vy_{F2}}}\qquad 遺傳型相關係數(r_G)=\frac{COVy_{F2}-COVxy_E}{\sqrt{(Vx_{F2}-Vx_E)\cdot(Vxy_{F2}-Vx_E)}}$$

$$其中，COVxy_E=\frac{1}{2}(COVxy_{P1}+COVxy_{P2})$$

$$Vx_E=\frac{1}{2}(Vx_{P1}+Vx_{P2})\ ;\ Vy_E=\frac{1}{2}(Vy_{P1}+Vy_{P2})$$

此處，$COVxy_{F2}$ $COVxy_{P1}$ 及 $COVxy_{P2}$ 依次表 F_2、P_1 及 P_2 之 x 性狀與 y 性狀之變積 (covariance)；Vx_{F2}、Vy_{F2}、Vx_{P1}、Vy_{P1}、Vx_{P2}；及 Vy_{P2} 乃分別爲 F_2，P_1 及 P_2 之 x 性狀及 y 性狀之變方 (variance)。

藉以上公式估得之表現型相關係數，繼續以路徑係數之分析，以探討 4 產量構成要素對秈稉雜交後代 F_2 單株穀產量之直接及間接影響程度，以明瞭各性狀對單株穀產量發生變異所占之相對重要性。

結　　果

一、雜交親本暨 F_2 集團各性狀之比較

茲將調查供試兩秈稉間之 F_2 雜交組合及各該親本諸性狀之平均，按組合別及親品種與 F_2 雜種後裔之不同，加以適當之平均值差異的顯著性測定，其結果列如表1。由表1單株穀產量之觀察知：在嘉農秈 11 號×臺農 67 號此秈×稉組合內，秈稻親本嘉農秈 11 號比稉稻親本臺農 67 號有較高之單株穀產量；而兩者之雜交 F_2 集團的單株穀產量則高出兩親中間值，惟與相對高產親本嘉農秈 11 號之單株穀產量的差距亦達 5 %之顯著水準。反之，在臺南 5 號×臺中在來 1 號之稉×秈組合中，稉稻親本臺南 5 號則此秈稻親本臺中在來1號有較高之單株穀產量；而其 F_2 集團單株穀產量之平均雖略高於相對高產稉稻親，但兩者間之差異並不顯著，亦即 F_2 集團單株穀產量之平均與高產親本者相似。

至於兩雜交 F_2 集團產量構成 4 要素之表現，則除秈×稉組合 F_2 集團之平均一穗穎花數略低於其兩秈稉親本及稉×秈組合 F_2 集團之千粒重均較其兩親本重外，其餘產量構成要素之表現概爲 F_2 集團之平均值介乎其各該兩親本之中間且略偏向其中之一親本，惟其偏向之趨勢及其與該較接近親本間之表現是否有差異存在，兩類雜交組合則並不一致。

表 1. 親本與 F_2 後裔各性狀之比較

Table 1. A comparision of means of various characters anomg parents and their F_2s

Parents and crosses	Panicle number/plant	Mean spikelet number/plant	Seed setting (%)	1,000-grain weight (g)	Grain yield /plant (g)
Chianung-Sen 11	11.9 a[a]	137.2 a	73.6 a	19.9 a	23.6 a
F_2	11.2 a	128.1 b	72.6 a	20.2 a	21.2 b
Tainung 67	10.7 a	131.0 ab	48.0 b	22.4 b	15.0 c
Tainan 5	8.7 a	121.4 a	60.1 a	18.9 a	11.7 a
F_2	10.1 b	113.2 ab	48.5 b	22.5 b	12.3 a
Taichung-Native 1	10.2 b	100.6 b	49.4 b	20.3 c	9.5 b

a. means followed by the same letter are not significantly different at 5% level.

二、兩雜種集團諸產量性狀間之相關分析

相關係數乃表示各性狀彼此間相互關係之程度，由 F_2 雜種分離世代估得之相關乃表現型相關，其包括遺傳型及環境相關等兩部分。而遺傳相關爲控制該兩性狀表現之遺傳因子間連鎖或遺傳因子多效性效應之結果，環境相關則係環境因子對該兩性狀表現之影響，屬環境效果，易造成育種家之錯覺。本研究藉變方及變積之分析，曾分別估算兩雜交組合諸產量性狀間之各類相關，並將估得兩組合之表現型相關係數按適合之顯著性水準加以顯著性測定，至於遺傳型相關係數因無法行顯著性測驗，故暫按表現型相關係數之顯著性水準，加以適當之劃分，至於環境相關。因其值概低，如仿表現型相關係數之顯著水準予以測定時多未顯著。故本研究僅將表現型及遺傳型等兩類相關係數之測驗結果示於圖1。

綜覽圖1可發現兩類雜交組合諸產量有關性狀彼此間之遺傳型相關概較表現型者密切。同時圖1亦顯示兩雜交組合之單株穀產量與單株之穗數，平均一穗穎花數，結實百分率及千粒重呈極顯著之正相關。若穗數與平均一穗穎花數則呈負相關關係，惟其或爲顯著負相關或係極顯著負相關則視秈×稉或稉×秈之不同而異。至於穗數與平均一穗穎花數，結實百分率及千粒重等3個產量構成要素間及此3個產量構成要素間之相關值則均不顯著，亦即該等性狀間俱屬無相關。

三、兩雜種集團 F_2 單株穀產量之路徑分析

水稻單株穀產量構成要素之選定因人而異，有以株高、穗長、穗重及穗數爲單株穀產量構成要素者[1]有以穗數、每穗粒數及千粒重等三性狀爲單株穀產量構成要素者[15,16]。惟筆者以爲由單株之穗數、平均一穗花數、結實百分率及千粒重等 4 個性狀來決定單株之穀產量者實至爲詳實妥善。故本研究據此觀念而探討單株之穗數、平均一穗花穎數、結實百分率及千粒重等 4 個性狀對單株穀產量之直接及間接影響程度。茲將其因果關係圖示如圖2。圖 2 中，單矢線 P_{ij} 爲路徑係數，表第 j 性狀對第 i 性狀單株穀產量之直接影響方向；雙矢線 r_{ij} 爲相關係數，乃第 i 性狀與第 j 性狀之相關值。而吾人得經由 $r_{ij}=P_{ij}+\sum_{i\neq j}^{n=5} P_{ij}\cdot r_{ij}$ 所構成之聯立方程式，即可解得各性狀之路徑係數。再藉 $1=\sum_{j=2}^{n=5} P^2_{ij}+2\sum_{i\neq j}^{n=5} P_{ij}\cdot r_{ij}\cdot P_{ij}+P^2_{iR}$ 之關係式以求得剩餘因子之路徑係數值。茲將估算結果示於表2。

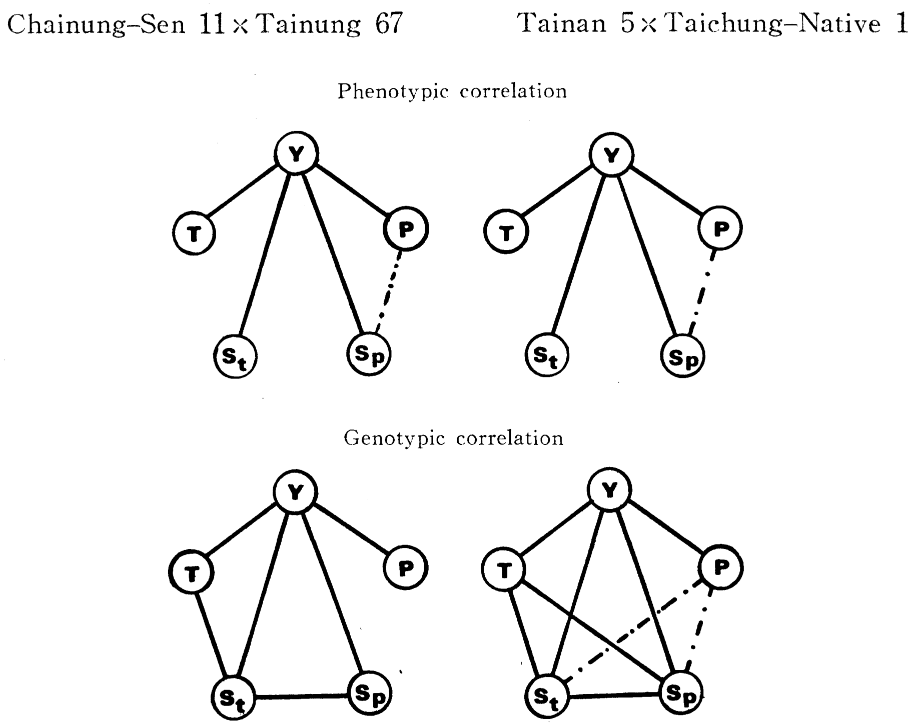

圖 1. 兩類雜交組合各性間之表現型及遺傳型相關

Fig. 1. Phenotypic and genotypic correlation coefficients among five characters in two rice crosses

Y : single plant grain yield, P : panicle number, Sp : mean spikelet number, St : seed setting, T : 1,000 grain yield.

——— Positive correlation, significant at 1% level
——·—— Negative correlation, significant at 1% level
- - - - Positive correlation, significant at 5% level
- - · - - Negative correlation, significant at 5% level

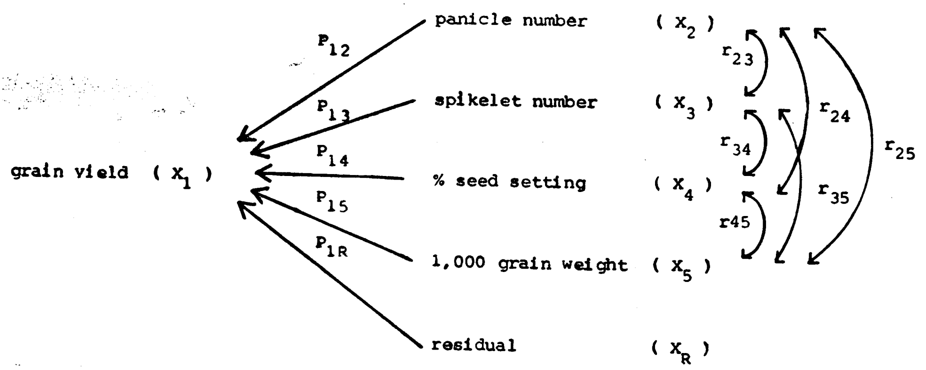

圖2. 產量構成要素與單株穀產量之因果關係圖

Fig. 2. Path diagram of single-plant grain yield in association with yield components

表 2. 兩類雜交組合產量構成要素對穀產量影響之路徑係數

Table 2. The path coefficients of yield components influncing grain yield in *indica* × *sinica* and *sinica* x *indica*

Effect type	Chainung-Sen 11 × Tainung 67	Tainan 5 × Taichung-Native 1
effect of panicle number on grain yield		
direct effect	0.625	0.562
indirect effect via spikelet number	− 0.077	− 0.155
indirect effect via % seed setting	0.026	− 0.001
indirect effect via 1,000-grain weight	− 0.001	− 0.001
combined effect	0.571	0.405
effect of spikelet number on grain yield		
direct effect	0.516	0.545
indirect effect via % seed setting	0.000	− 0.045
indirect effect via 1,000-grain weight	− 0.006	− 0.007
indirect effect via panicle number	− 0.093	− 0.160
combined effect	0.417	0.334
effect of % seed setting on grain yield		
direct effect	0.376	0.645
indirect effect via 1,000-grain weight	− 0.002	− 0.007
indirect effect via panicle number	0.044	− 0.001
indirect effect via spikelet number	0.000	− 0.038
combined effect	0.418	0.608
effect of 1,000-grain weight on grain yield		
direct effect	0.298	0.255
indirect effect ia panicle number	− 0.002	− 0.003
indirect effect via spikelet number	− 0.010	− 0.015
indirect effect via % seed setting	− 0.003	− 0.019
combined effect	0.283	0.218
residual	0.434	0.305

綜覽表 2 可發現兩類雜交組合 4 產量構成要素對單株穀產量之路徑係數值概爲正值；而各性狀經由其他性狀對單株穀產量之間接效應值之爲正抑負，兩類組合並無一致之趨勢。換言之，兩類雜交組合產量構成 4 要素對單株穀產量之發生變異均爲正方向之直接影響，而各產量構成要素經由其他性狀對單株穀產量變異之間接影響方向則無一定規則可循。

就組合別詳言之：在嘉農秈 11 號×臺農 67 號組合內，單株之穗數對單株穀產量之直接效應值在諸產量構成要素中爲最大者，其次爲平均一穗穎花數，再次爲結實百分率，終爲穀粒之千粒重。就中，穗數及平均一穗穎花數對單株穀產量之綜合效應均較各該性狀對單株穀產量之直接效應值爲低，考其原因乃在穗數或平均一穗穎花數經由平均一穗穎花數或穗數對單株穀產量之間接效應值爲負值，且其值則不小，故大大地影響各該性狀對單株穀產量之直接效應值，以致各該性狀之綜合效應值因之降

低。而結實百分率對單株穀產量之綜合效應值則較其之直接效應值爲大，此乃結實百分率經由穗數對單株穀產量之間接效應值爲正值，且其值又不甚小之故。至於千粒重經由其他三產量構成要素對單株穀產量之間接效應值雖均爲負值，但各值概小，故千粒重對單株穀產量之直接效應值與綜合效應值極爲相近。綜言之，數據顯示在此秈×稉之組合中，單株之穗數的表現每每與平均一穗穎花數之表現互爲制衡，相互拮抗；而千粒重之表現受其他性狀之制衡作用則很小。

而在臺南5號×臺中在來一號此組合中，諸產量構成要素對單株穀產量直接效應值之大小順序與前一秈×稉組合者並不相雷同。在本稉×秈組合中，對單株穀產量直接效應值最大之產量構成要素爲結實百分率，次爲穗數，再爲平均一穗穎花數，終爲千粒重。一如秈×稉組合內性狀表現有互爲拮抗之情形，本稉×秈組合中，結實百分率對單株穀產量之直接效應值也因其經由平均一穗穎花數對單株稻產量之間接效應值而抵消，故結實百分率對單株穀產量之綜合效應值因之略略降低。而穗數及平均一穗穎花數對單株產量之直接效應值原十分接近，同時該兩性狀經由其他性狀對單穀產量之間接效應值亦均爲負值，但因穗數之直接效應值僅受其經由平均一穗穎花數對單株穀產量間接應值之大幅牽制；而平均一穗穎花數者除受其經由穗數對單株穀產量間接效應值之鉅幅影響外，尙受其經由結實百分率於千粒之間接效效應值的制衡，致平均一穗穎花數對單株穀產量之綜合效應值遂遠較穗數者小。至於千粒重經由其他性狀對單株穀產量之間接效應值則如秈×稉組合者，其值亦皆爲負值，惟各該間接效應值均遠較秈×稉組合者爲鉅，故千粒重對單株穀產量之綜合效應值與其直接效應值之差距也因之而較秈×稉組合者爲大。亦即本稉×秈組合之數據亦顯示單株穗數之表現與平均一穗穎花數者互爲掣肘，而千粒重之表現受其他性狀之制衡作用則較秈×稉者爲著。

討　　論

就表面上言，稻株之穀產量爲一單一之性狀。惟實質上考慮，則稻株之穀產量實由稻株之穗數，平均一穗穎花數、千粒重及結實百分率等產量構成要素所累積成之一種複合性狀。而其諸產量構成要素對穀產量之貢獻，則各性狀所扮演之角色的重性應非均等。因此在育種選拔時應較重視何種性狀殊值研討。

湯著[9]載印度 Abrahan(1954)曾用 25 個品種，調查每株之產量、穗數、每穗粒數、千粒重及抽穗期之莖數，計算各性狀對產量之判別函數，作爲選拔多產品種之參考；日人岡彥一用臺灣品種雜交 F_5 個體選拔之穗重、穗數、稈長與每株穗重間相關之計算而另創一在分離集團個體選拔之辨別式[9]。本研究則利用路徑係數分析法，探討秈×稉及稉×秈兩類雜交 F_2 集團中，產量構成要素對單株穀產量變異性之決定性與各產量構成要素間之關係以爲育種家選種之參考。結果發現秈×稉及稉×秈兩類異型間雜交組合的產量構成要素對單株穀產量變異性決定程度之大小順序並不一致，且產量構成要素間之關係也呈現若干程度之差異（表2）。其中，在嘉農秈 11 號×臺農 67 號之秈×稉組合數據所顯示之：穗數與平均一穗穎花數對穀產生量變異性之決定程度較結實百分率及千粒重者爲大；同時穗數及平均一穗穎花數對單株穀產量之貢獻有强烈拮抗作用存在；以及千粒重經由其他 3 產量構成要素對單穀產量之間接影響皆爲負值等之結果，恰均與林[5]以 IR-9-60×臺南 5 號 F_2 集團爲材料之研究分析結果完全相符，而與王[1]以 Dular ×嘉農 242 F_2 材料之分析數據顯示穗數與穗重爲對單株穀產量最具影響力之產量構成要素的結果部份相似。

而本研究臺南 5 號×臺中在來 1 號之稉 × 秈雜交組合中，數據顯示結實百分率爲對單株穀產量變異性決定性較大之產量構成要素，而穗數及平均一穗穎花數對單株穀產量變異性之決定程度則約略相等，均略小於結實百分率者而遠大於千粒重者，而諸性狀之拮抗情形則一如秈 × 稉之雜交組合（表2）。此似顯示本雜交組合可能爲栽培稻秈稉異型間雜交時，秈＝稉不稔性 (*indica-japonica* sterility) 現象較爲嚴重的一個組合。因根據湯[9]之綜合論述：在不同組合中，品種間雜種不稔程度

之差別殊大，其變域自0至 90 %以上。亦即並非所有日本型×印度型稻雜種皆呈部份不稔，而僅係在此兩亞種內少量之雜交組合此現象較嚴重[9]。湯(1967)此種論述似亦可部份證之於本研究嘉農秈11 號×臺農 67 號組合之結實百分率平均高達 72.6 %，而臺南 5 號×臺中在來 1 號者僅達 48.5 %（表1）之結果。然而栽培稻秈稉雜種間之此不稔性現象專家學者之研究，雖尚未獲一肯定且一致之解釋，但學者研究報告也指出品種間雜種不稔程度雖頗大，然不論 F_1 其不稔程度如何，有相當高百分率 F_2 植株呈完全可稔或高度可稔者[9]；有隨世代之增加而稔實增進且 F_3 選拔即有效者[12]，亦即栽培稻秈稉兩亞種間之雜種不稔性並未構成亞種間雜交育種之嚴重妨礙。反因爲亞種間生態、生理及血緣之互異而有利育種家造成更大之遺傳變異，從而組合秈稉理想性狀於一品種（系）。此可由若干主要稻米生產國家，若干優良新品種即由秈稉雜種育成予以事實上之確證[9]。也就是本研究臺南 5 號× 臺中在來一號之結實百分率低下致其對單株穀產量變異性決定程度爲 4 產量構成要素中之最大者的現象，並不會强烈妨礙經由本稉×秈組合而育成優品品系之可能性。

基於以上之論點，並援王[1]、林[5]、湯[9]、盧及孔[12]等氏之報告，再參照本研究之數據顯示，於秈×稉或稉×秈之 F_2 材料行譜系法行選拔時，穗數及平均一穗穎花數應是育種應較重視的兩性狀，然因爲該兩種產量構成性狀之表現對單株穀產量變異性之貢獻具拮抗作用，故最適穗數與合理之平均一穗穎花數之妥善搭配，亦應爲育種家須加考慮注意者。至於米質特性互異秈稉異型稻雜交後代米粒食用品質之遺傳變異，據謝及郭（1981，未發表資料）之研究顯示吾人極容易從該等秈×稉或稉×秈等亞種間之雜交集團選獲目標之食用品質品系，惟謝及郭（1981）之數據也顯示食用品質性狀與產量構成4要素間並無相關關係存在，此實在是藉秈稉稻異型間之雜交以育成良質豐產稻品種之另一須面對的問題。

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Genetical and breeding studies in the crosses between *indica X sinica* rices

1. Path coefficient analysis of single-plant grain yield[1]

Y. C. Kuo, and T. M. Chang[2]

Summary

The prestent studies are to compare the effect of four yield components on the variability of single-plant grain yield of rice in *indica*×*sinica* and *sinica*×*indica* crosses by the technique of path coefficient analysis.

The significant positive correlations between four yield components and single-grain yield were observed in both crosses. From the path coefficient analysis, it was observed that the order and degree of effect of the respective yield component on the grain yield differed from cross combination The order of effect on grain yield was found to be number of panicles, mean number of spikelets, percent seed setting and 1,000 grain weight in the *indica* × *sinica* cross ; and percent seed setting, number of panicles, mean number of spikelets and 1,000 grain weight in the *sinica* ×*indica* cross.

It was suggeted that in rice breeding, number of panicles and mean number of spikelets should be used as the main selection criteria for selecting grain yield from either *indica*×*sinica* or *sinica*×*indica* cross.

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Calculating linkage intensities by product method[1]

Ching Liu[2]

Abstract : General formulae for testing the expected phenotypic ratios and for detecting the linkage are given. Tables for obtaining crossing over values by the product method for different mating types and different phenotypic ratios are appended. Standard error can also be found along with the estimate. An example is given to illustrate the use of the appended tables.

Product method has been suggested to estimate the linkage intensity between two factors from F_2 or backcross of double heterozygotes (Fisher and Balmukand, 1928 ; Immer, 1930 ; Bailey, 1961 and Fisher, 1970). The product method is easy to use and the calculation of crossing over value can be greatly facilitated when suitable tables are available, it is affected the least by differential mortality of gamates or zygotes (Immer, 1930), it has in large samples a variance as small as possible (Fisher, 1970 and Liu, 1981), and it is easy to tabulate.

Let the four phenotypic classes of the progeny be denoted by AB, Ab, aB and ab and designating their observed frequencies by a, b, c and d respectively . Further, let expected phenotypic ratios of A : a and B : b be $\lambda_1 : \lambda_2$ and $\mu_1 : \mu_2$ respectively. Test of expected phenotypic ratios and the detection of linkage may be performed by using the three χ^2's listed in the following table, χ^2_A and χ^2_B are ratio χ^2's and χ^2_L linkage χ^2, all with one degree of freedom.

	Phenotype				
	AB	Ab	aB	ab	Total
Observed nos.	a	b	c	d	n
Expected nos.	$\lambda_1 u_1 D$	$\lambda_1 u_2 D$	$\lambda_2 u_1 D$	$\lambda_2 u_2 D$	n

A : a $=\lambda_1 : \lambda_2$, B : b $= u_1 : u_2$ and $D = n/(\lambda_1+\lambda_2)(u_1+u_2)$

(1) $\chi^2_A = [\lambda_2(a+b) - \lambda_1(c+d)]^2 / [(\lambda_1\lambda_2^2 u_1 + \lambda_1\lambda_2^2 u_2 + \lambda_1^2\lambda_2 u_1 + \lambda_1^2\lambda_2 u_2)D]$

(2) $\chi^2_B = [u_2(a+c) - u_1(b+d)]^2 / [(\lambda_1 u_1 u_2^2 + \lambda_1 u_1^2 u_2 + \lambda_2 u_1 u_2^2 + \lambda_2 u_1^2 u_2)D]$

(3) $\chi^2_L = [u_2(\lambda_2 a - \lambda_1 c) - u_1(\lambda_2 b - \lambda_1 d)]^2 / [\lambda_1\lambda_2 u_1 u_2(\lambda_1 u_1 + \lambda_1 u_2 + \lambda_2 u_1 + \lambda_2 u_2)D]$

It is easy to see that the ratio of the product ad(or bc)to the product bc (or ad) is a function of p, i. e., crossing over value. By subsituting the theoretical frequencies of a, b, c and

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d into the ratio, we have an equation in the form ad/bc (or bc/ad)=func. (p), a quadratic equation of which p is taken to be the positive solution. The product equations for different mating types and different phenotypic ratios are given by Liu (1981). In calculating linkage intensities by this method, the observed frequencies for the four classes, a, b, c and d are substituted in the equation and the crossing over value determined. Formulae for the sampling variances of crossing over values calculated by the product method may be developed from the general equation given by Fisher (1970) and the explicit formulae for variances can be found in Liu (1981).

In estimating linkage intensities from the equations given by Liu (1981), it is necessary to solve a quadratic equation. Although this causes no difficulty, it may be rather laborious under some conditions and will always be time consuming. It is a great advantage of the product method that it permits itself readily to the calculation of tables from which crossing over values and their standard errors may be determined with the entering of the observed ratio of product ad/bc (for repulsion) or bc/ad (for coupling).

Tables for calculating linkage intensities by the product method for two 3 : 1 ratios have been given by Fisher and Balmukand (1928) and more extended tables have been presented by Immer (1930). Tables appended in this paper include some even more complex ratios than those of Immer's and substitute the probable error used in Immer's tables by the standard error which is far more useful in making statistical inferences.

By referring to the appended tables (Table 1 to Table 21), the labor of culculating linkage intensities can be materially reduced. Crossing over value can be determined by a given value of the ratio of products ad/bc or bc/ad for different mating types and different phenotypic ratios. In these tables, the ratio of products for repulsion is given as ad/bc and for coupling bc/ad. This is done because it is more convenient to keep the ratios less than one for all crossing over values less than 0.5.

By the aid of the appended tables, the estimation of crossing over values by the product method then simply involves only the calculation of ad/bc or bc/ad from the four observed phenotypic classes. If the value of ad/bc or bc/ad is not on the tables, interpolation may be employed to find the linkage intensity. The standard error of the estimate is obtained by dividing the tabulated standard error by the square root of the total frequency, i. e., $\sqrt{n}$.

As an example of the use of the product method, the following data taken from an experiment carried out by M. H. Lin at the Taiwan Agricultural Research Institute in 1980 is used. A ligureless (lg) and narrow leaf (nal) mutant rice (H106) was crossed with a ligured (Lg) and broad leaf (Nal) normal one (Tainan No. 5). The F_2 may be classified as under :

LgNal (a)	Lgnal (b)	lgNal (c)	lgnal (d)	Total (n)
3511	172	188	1009	4880

Three single degree of freedom χ^2's for testing the expected phenotypic ratios and for detecting the linkage are as follows :

$\chi^2_{Lg}=0.578$, Pr $(\chi_1^2>0.578)=0.54662$

$\chi^2_{Nal}=1.662$, Pr $(\chi_1^2>1.662)=0.19411$

$\chi^2_L=3017.444$, Pr $(\chi^2_1>3017.444)=0$

Two ratio χ^2's show that the expected 3 : 1 and 3 : 1 ratios are satisfactory realized, but the linkage χ^2 indicate that there is strong evidence for linkage. Since the cross is one of coupling, we calculate bc/ad=0.00913. By interpolation in Table 1 we found the crossing over value to be 0.07741. From the same table we also find by interpolation that the standard error is 0.2301 which, divided by $\sqrt{4880}$, gives a standard error of the above estimate of crossing over value of 0.00401.

If complementary, duplicate or inhibiting factors had been involved in determining one or both of the character pairs from a cross, we would have estimated the linkage intensity by using the appropriate table depending on the expected phenotypic ratios.

It is noted that the probabilities of the four phenotypes (AB, Ab, aB and ab) from a tissue culture of F_1 anther are identical to those from a backcross of F_1 to either parent. Therefore, the anther culture data may be analyzed as though they were the backcross data for linkage estimation, regardless of whether the materials are haploids, polyploids through chromosome multiplying or the pooled one.

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連鎖強度之乘積法估算[1]

劉 清[2]

中文摘要

本文導出測驗外表型分別比及測驗遺傳連鎖是否存在之一般化公式。若遺傳連鎖顯著存在，則視各種不同交配類型及各種不同分離比，連鎖强度之乘積法估值可經由本文中之附表直接查出，附表中並列有各估值之標準偏差。文末附有一例以說明本文附表的使用法。

1. 臺灣省農業試驗所 研究報告 第 995 號。

2. 本所農藝系研究員。臺灣省 臺中縣 霧峰鄉。

Table 1. Crossing over value (COV) and their standard errors based on the product method when both character pair are determined by a single factor difference-3 : land 3 : 1 for F_2 orl : 1 and 1 : 1 for backcross (BC)

COV %	Ratio of products, %				$\sqrt{n}$ × (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	0.020	0.010	0.014	0.010	99.988	9.950	10.008	9.950
2	0.080	0.042	0.055	0.042	99.950	14.000	14.166	14.000
3	0.180	0.096	0.126	0.096	99.888	17.059	17.365	17.059
4	0.321	0.174	0.228	0.174	99.800	19.596	20.070	19.596
5	0.503	0.277	0.363	0.277	99.688	21.794	22.460	21.794
6	0.727	0.407	0.532	0.407	99.552	23.749	24.627	23.749
7	0.992	0.567	0.737	0.567	99.391	25.515	26.626	25.515
8	1.301	0.756	0.979	0.756	99.206	27.129	28.492	27.129
9	1.653	0.978	1.262	0.978	98.997	28.618	30.251	28.618
10	2.051	1.235	1.586	1.235	98.764	30.000	31.920	30.000
11	2.495	1.528	1.954	1.528	98.509	31.289	33.513	31.289
12	2.986	1.860	2.369	1.860	98.230	32.496	35.041	32.496
11	3.527	2.233	2.832	2.233	97.928	33.630	36.511	33.630
13	4.118	2.650	3.347	2.650	97.604	34.699	37.931	34.699
15	4.763	3.114	3.915	3.114	97.259	35.707	39.306	35.707
16	5.462	3.628	4.540	3.628	96.892	36.661	40.641	36.661
17	6.218	4.195	5.225	4.195	96.504	37.563	41.941	37.563
18	7.033	4.819	5.973	4.819	96.096	38.419	43.207	38.419
19	7.911	5.502	6.787	5.502	95.667	39.230	44.444	39.230
20	8.854	6.250	7.670	6.250	95.219	40.000	45.653	40.000
21	9.865	7.066	8.628	7.066	94.752	40.731	46.838	40.731
22	10.948	7.955	9.663	7.955	94.266	41.425	47.999	41.425
23	12.107	8.922	10.780	8.922	93.762	42.083	49.139	42.083
24	13.345	9.972	11.984	9.972	93.241	42.708	50.259	42.708
25	14.667	11.111	13.279	11.111	92.702	43.301	51.360	43.301
26	16.077	12.345	14.671	12.345	92.147	43.863	52.444	43.863
27	17.581	13.680	16.164	13.680	91.576	44.396	53.512	44.396
28	19.185	15.123	17.766	15.123	90.990	44.900	54.565	44.900
29	20.894	16.683	19.481	16.683	90.388	45.376	55.604	45.376
30	22.715	18.367	21.318	18.367	89.771	45.826	56.629	45.826
31	24.654	20.185	23.283	20.185	89.141	46.249	57.641	46.249
32	26.721	22.145	25.383	22.145	88.497	46.648	58.641	46.648
33	28.922	24.259	27.627	24.259	87.839	47.021	59.629	47.021
34	31.268	26.538	30.025	26.538	87.169	47.371	60.607	47.371
35	33.767	28.994	32.585	28.994	86.486	47.697	61.574	47.697
36	36.431	31.641	35.317	31.641	85.792	48.000	62.530	48.000
37	39.270	34.492	38.234	34.492	85.086	48.280	63.477	48.280
38	42.299	37.565	41.346	37.565	84.369	48.539	64.415	48.539
39	45.530	40.876	44.667	40.876	83.640	48.775	65.343	48.775
40	48.980	44.444	48.211	44.444	82.902	48.990	66.262	48.990
41	52.663	48.291	51.993	48.291	82.153	49.183	67.173	49.183
42	56.598	52.438	56.029	52.438	81.395	49.356	68.075	49.356
43	60.806	56.910	60.337	56.910	80.626	49.508	68.969	49.508
44	65.307	61.735	64.937	61.735	79.849	49.639	69.855	49.639
45	70.126	66.942	69.850	66.942	79.062	49.749	70.733	49.749
46	75.289	72.565	75.098	72.565	78.267	49.840	71.602	49.840
47	80.824	78.640	80.709	78.640	77.463	49.910	72.464	49.910
48	86.763	85.207	86.708	85.207	76.650	49.960	73.317	49.960
49	93.142	92.311	93.128	92.311	75.829	49.990	74.163	49.990
50	100.000	100.000	100.000	100.000	75.000	50.000	75.000	50.000

Table 2. Crossing over value (COV) and their standard errors based on the product method when one character pair is determined by a single factor difference and the other character pair by two complementary factor differences-3 : 1 and 9 : 7 for F_2 or 1 : 1 and 1 : 3 for backcross (BC)

COV %	Ratio of products, %				$\sqrt{n}$ × (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	33.350	0.513	0.519	0.513	5,164.391	19.754	16.124	19.754
2	33.400	1.051	1.075	1.051	2,582.814	27.601	22.540	27.601
3	33.484	1.617	1.670	1.617	1,722.563	33.406	27.318	33.406
4	33.601	2.211	2.306	2.211	1,292.641	38.129	31.243	38.129
5	33.752	2.834	2.983	2.834	1,034.849	42.147	34.627	42.147
6	33.937	3.488	3.703	3.488	863.121	45.656	37.632	45.656
7	34.157	4.173	4.467	4.173	740.570	48.775	40.354	48.775
8	34.412	4.891	5.277	4.891	648.753	51.582	42.858	51.582
9	34.702	5.644	6.133	5.644	577.424	54.131	45.188	54.131
10	35.029	6.433	7.038	6.433	520.434	56.464	47.376	56.464
11	35.392	7.259	7.992	7.259	473.871	58.610	49.447	58.610
12	35.793	8.124	8.997	8.124	435.126	60.594	51.421	60.594
13	36.233	9.029	10.054	9.029	402.393	62.435	53.312	62.435
14	36.711	9.977	11.166	9.977	374.382	64.148	55.134	64.148
15	37.231	10.970	12.333	10.970	350.146	65.748	56.896	65.748
16	37.792	12.008	13.557	12.008	328.977	67.244	58.607	67.244
17	38.395	13.095	14.839	13.095	310.331	68.647	60.275	68.647
18	39.043	14.232	16.182	14.232	293.785	69.963	61.906	69.963
19	39.736	15.422	17.586	15.422	279.007	71.199	63.505	71.199
20	40.476	16.667	19.054	16.667	265.729	72.363	65.077	72.363
21	41.265	17.969	20.586	17.969	253.736	73.458	66.627	73.458
22	42.105	19.332	22.185	19.332	242.850	74.489	68.159	74.489
23	42.997	20.757	23.852	20.757	232.926	75.461	69.675	75.461
24	43.943	22.249	25.588	22.249	223.841	76.377	71.179	76.377
25	44.946	23.810	27.396	23.810	215.494	77.239	72.675	77.239
26	46.009	25.443	29.278	25.443	207.798	78.052	74.165	78.052
27	47.133	27.152	31.233	27.152	200.679	78.817	75.652	78.817
28	48.321	28.941	33.265	28.941	194.073	79.537	77.138	79.537
29	49.578	30.813	35.375	30.813	187.926	80.214	78.626	80.214
30	50.904	32.773	37.564	32.773	182.191	80.849	80.118	80.849
31	52.305	34.825	39.834	34.825	176.827	81.445	81.616	81.445
32	53.783	36.975	42.187	36.975	171.797	82.003	83.123	82.003
33	55.343	39.226	44.623	39.226	167.070	82.524	84.641	82.524
34	56.989	41.585	47.145	41.585	162.618	83.010	86.172	83.010
35	58.725	44.056	49.754	44.056	158.416	83.461	87.719	83.461
36	60.557	46.646	52.452	46.646	154.442	83.879	89.283	83.879
37	62.489	49.362	55.238	49.362	150.676	84.264	90.868	84.264
38	64.526	52.210	58.115	52.210	147.100	84.618	92.475	84.618
39	66.676	55.198	61.084	55.198	143.699	84.941	94.108	84.941
40	68.944	58.333	64.146	58.333	140.459	85.234	95.768	85.234
41	71.338	61.625	67.302	61.625	137.367	85.497	97.458	85.497
42	73.865	65.081	70.551	65.081	134.410	85.732	99.182	85.732
43	76.532	68.712	73.897	68.712	131.580	85.937	100.942	85.937
44	79.350	72.527	77.337	72.527	128.865	86.115	102.741	86.115
45	82.328	76.540	80.874	76.540	126.257	86.264	104.583	86.264
46	85.475	80.760	84.508	80.760	123.748	86.386	106.472	86.386
47	88.803	85.202	88.237	85.202	121.331	86.481	108.410	86.481
48	92.324	89.879	92.063	89.879	118.998	86.549	110.401	86.549
49	96.052	94.806	95.984	94.806	116.745	86.589	112.452	86.589
50	100.000	100.000	100.000	100.000	114.564	86.603	114.564	86.603

Table 3. Crossing over value (COV) and their standard errors based on the product method when one character pair is determined by a single factor difference and the other character pair by two duplicate factor differences-3 : 1 and 15 : 1 for F_2 or 1:1 and 3:1 for backcross (BC)

COV %	Ratio of products, %				$\sqrt{n}$ × (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	0.028	0.513	0.512	0.513	199.987	19.754	28.100	19.754
2	0.110	1.051	1.048	1.051	199.946	27.601	39.491	27.601
3	0.248	1.617	1.609	1.617	199.879	33.406	48.075	33.406
4	0.441	2.211	2.197	2.211	199.786	38.129	55.191	38.129
5	0.690	2.834	2.811	2.834	199.665	42.147	61.361	42.147
6	0.995	3.488	3.455	3.488	199.518	45.656	66.857	45.656
7	1.356	4.173	4.127	4.173	199.344	48.775	71.839	48.775
8	1.775	4.891	4.831	4.891	199.143	51.582	76.415	51.582
9	2.252	5.644	5.567	5.644	198.916	54.131	80.658	54.131
10	2.787	6.433	6.336	6.433	198.662	56.464	84.624	56.464
11	3.382	7.259	7.140	7.259	198.382	58.610	88.353	58.610
12	4.038	8.124	7.981	8.124	198.075	60.594	91.878	60.594
13	4.755	9.029	8.860	9.029	197.742	62.435	95.224	62.435
14	5.535	9.977	9.778	9.977	197.383	64.148	98.412	64.148
15	6.379	10.970	10.739	10.970	196.997	65.748	101.460	65.748
16	7.288	12.008	11.743	12.008	196.586	67.244	104.382	67.244
17	8.265	13.095	12.792	13.095	196.148	68.647	107.190	68.647
18	9.311	14.232	13.890	14.232	195.685	69.963	109.894	69.963
19	10.427	15.422	15.037	15.422	195.196	71.199	112.503	71.199
20	11.616	16.667	16.237	16.667	194.681	72.363	115.025	72.363
21	12.880	17.969	17.492	17.969	194.140	73.458	117.468	73.458
22	14.221	19.332	18.806	19.332	193.574	74.489	119.835	74.489
23	15.641	20.757	20.180	20.757	192.983	75.461	122.134	75.461
24	17.143	22.249	21.618	22.249	192.366	76.377	124.368	76.377
25	18.730	23 810	23.123	23.810	191.725	77.239	126.542	77.239
26	20.405	25.443	24.700	25.443	191.058	78.052	128.659	78.052
27	22.171	27.152	26.351	27.152	190.366	78.817	130.722	78.817
28	24.032	28.941	28.081	28.941	189.649	79.537	132.735	79.537
29	25.991	30.813	29.894	30.813	188.908	80.214	134.701	80.214
30	28.051	32.773	31.795	32.773	188.141	80.849	136.620	80.849
31	30.219	34.825	33.789	34.825	187.351	81.445	138.497	81.445
32	32.497	36.975	35.882	36.975	186.535	82.003	140.332	82.003
33	34.890	39.226	38.079	39.226	185.695	82.524	142.128	82.524
34	37.404	41.585	40.386	41.585	184.831	83.010	143.885	83.010
35	40.044	44.056	42.810	44.056	183.943	83.461	145.606	83.461
36	42.816	46.646	45.359	46.646	183.030	83.879	147.292	83.879
37	45.727	49.362	48.039	49.362	182.093	84.264	148.944	84.264
38	48.782	52.210	50.861	52.210	181.132	84.618	150.563	84.618
39	51.990	55.198	53.833	55.198	180.147	84.941	152.150	84.941
40	55.357	58.333	56.964	58.333	179.138	85.234	153.706	85.234
41	58.893	61.625	60.266	61.625	178.104	85.497	155.231	85.497
42	62.605	65.081	63.750	65.081	177.047	85.732	156.728	85.732
43	66.505	68.712	67.430	68.712	175.965	85.937	158.195	85.937
44	70.601	72.527	71.319	72.527	174.859	86.115	159.634	86.115
45	74.905	76.540	75.431	76.540	173.728	86.264	161.046	86.264
46	79.249	80.760	79.785	80.760	172.573	86.386	162.431	86.386
47	84.186	85.202	84.398	85.202	171.393	86.481	163.788	86.481
48	89.190	89.879	89.290	89.879	170.189	86.549	165.120	86.549
49	94.456	94.806	94.482	94.806	168.960	86.589	166.425	86.589
50	100.000	100.000	100.000	100.00	167.705	86.603	167.705	86.603

Table 4. Crossing over value (COV) and their standard errors based on the product method when one character pair is determined by a single factor difference and the other character pair by two inhibiting factor differences-3 : 1 and 3 : 13 for F_2 or 1 : 1 and 1 : 3 for backcross (BC)

COV %	Ratio of products, %				$\sqrt{n}$ × (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	60.012	0.513	1.513	0.513	14,383.65	19.754	28.303	19.754
2	60.046	1.051	3.053	1.051	7,191.466	27.601	40.060	27.601
3	60.105	1.617	4.620	1.617	4,793.908	33.406	49.113	33.406
4	60.186	2.211	6.212	2.211	3,595.007	38.129	56.780	38.129
5	60.291	2.834	7.831	2.834	2,875.568	42.147	63.571	42.147
6	60.419	3.488	9.476	3.488	2,395.860	45.656	69.750	45.656
7	60.572	4.173	11.146	4.173	2,053.140	48.775	75.473	48.775
8	60.748	4.891	12.842	4.891	1,796.037	51.582	80.843	51.582
9	60.948	5.644	14.563	5.644	1,596.011	54.131	85.933	54.131
10	61.173	6.433	16.309	6.433	1,435.939	56.464	90.795	56.464
11	61.423	7.259	18.080	7.259	1,304.922	58.610	95.470	58.610
12	61.698	8.124	19.875	8.124	1,195.697	60.594	99.989	60.594
13	61.999	9.029	21.695	9.029	1,103.234	62.435	104.379	62.435
14	62.325	9.977	23.537	9.977	1,023.939	64.148	108.659	64.148
15	62.678	10.970	25.403	10.970	955.179	65.748	112.849	65.748
16	63.058	12.008	27.292	12.008	894.978	67.244	116.964	67.244
17	63.466	13.095	29.203	13.095	841.823	68.647	121.016	68.647
18	63.901	14.232	31.136	14.232	794.541	69.963	125.017	69.963
19	64.366	15.422	33.090	15.422	752.202	71.199	128.978	71.199
20	64.859	16.667	35.065	16.667	714.065	72.363	132.909	72.363
21	65.383	17.969	37.060	17.969	679.528	73.458	136.817	73.458
22	65.939	19.332	39.074	19.332	648.099	74.489	140.710	74.489
23	66.525	20.757	41.108	20.757	619.373	75.461	144.597	75.461
24	97.145	22.249	43.160	22.249	593.010	76.377	148.484	76.377
25	67.799	23.810	45.229	23.810	568.726	77.239	152.378	77.239
26	68.487	25.443	47.315	25.443	546.279	78.052	156.285	78.052
27	69.211	27.152	49.417	27.152	525.466	78.817	160.211	78.817
28	69.973	28.941	51.535	28.941	506.109	79.537	164.162	79.537
29	70.773	30.813	53.666	30.813	488.058	80.214	168.145	80.214
30	71.613	32.773	55.812	32.773	471.180	80.849	172.165	80.849
31	72.494	34.825	57.970	34.825	455.362	81.445	176.227	81.445
32	73.418	36.975	60.140	36.975	440.502	82.003	180.339	82.003
33	74.386	39.226	62.321	39.226	426.513	82.524	184.505	82.524
34	75.401	41.585	64.511	41.585	413.316	83.010	188.732	83.010
35	76.464	44.056	66.711	44.056	400.843	83.461	193.026	83.461
36	77.577	46.646	68.918	46.646	389.032	83.879	197.392	83.879
37	78.743	49.362	71.133	49.362	377.829	84.264	201.839	84.264
38	79.963	52.210	73.352	52.210	367.184	84.618	206.372	84.618
39	81.241	55.198	75.577	55.198	357.053	84.941	210.998	84.941
40	82.578	58.333	77.805	58.333	347.396	85.234	215.725	85.234
41	83.979	61.625	80.035	61.625	338.178	85.497	220.559	85.497
42	85.445	65.081	82.266	65.081	329.366	85.732	225.510	85.732
43	86.980	68.712	84.497	68.712	320.930	85.937	230.586	85.937
44	88.589	72.527	86.726	72.527	312.844	86.115	235.794	86.115
45	90.273	76.540	88.953	76.540	305.082	86.264	241.146	86.264
46	92.039	80.760	91.176	80.760	297.623	86.386	246.650	86.386
47	93.889	85.202	93.393	85.202	290.445	86.481	252.317	86.481
48	95.828	89.879	95.604	89.879	283.529	86.549	258.159	86.549
49	97.864	94.806	97.807	94.806	276.858	86.589	264.188	86.589
50	100.000	100.000	100.000	100.000	270.416	86.603	270.416	86.603

Table 5. Crossing over value (COV) and their standard errors based on the product method when one character pair is determined by a single factor difference and the other character pair by three complementary factor differences–3 : 1 and 27 : 37 for F_2 or 1 : 1 and 1 : 7 for backcross (BC)

COV	Ratio of products, %				$\sqrt{n}$ × (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
%	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	46.681	0.762	0.894	0.762	5790.434	28.062	18.753	28.062
2	46.724	1.549	1.826	1.549	3795.367	39.374	26.386	39.374
3	46.796	2.360	2.797	2.360	2530.410	47.846	32.167	47.846
4	46.898	3.199	3.808	3.199	1897.981	54.817	36.987	54.817
5	47.028	4.064	4.860	4.064	1518.562	60.811	41.195	60.811
6	47.188	4.957	5.952	4.957	1265.647	66.098	44.972	66.098
7	47.377	5.880	7.086	5.880	1085.020	70.841	48.427	70.841
8	47.597	6.832	8.263	6.832	949.572	75.147	51.630	75.174
9	47.847	7.816	9.482	7.816	844.243	79.090	54.632	79.090
10	48.127	8.832	10.746	8.832	759.995	82.725	57.470	82.725
11	48.439	9.881	12.053	9.881	691.079	86.094	60.173	86.094
12	48.783	10.965	13.406	10.965	633.662	89.229	62.761	89.229
13	49.159	12.085	14.804	12.085	585.088	92.157	65.254	92.157
14	49.569	13.243	16.247	13.243	543.462	94.899	67.666	94.899
15	50.012	14.439	17.738	14.439	507.393	97.472	70.008	97.472
16	50.490	15.675	19.275	15.675	475.839	99.892	72.292	99.892
17	51.003	16.952	20.860	16.952	448.003	102.170	74.526	102.170
18	51.553	18.274	22.493	18.274	423.263	104.319	76.719	104.319
19	52.141	19.640	24.175	19.640	401.130	106.346	78.876	106.346
20	52.767	21.053	25.905	21.053	381.212	108.261	81.006	108.261
21	53.432	22.514	27.684	22.514	363.192	110.070	83.112	110.070
22	54.139	24.027	29.512	24.027	346.810	111.781	85.200	111.781
23	54.887	25.592	31.391	25.592	331.852	113.397	87.275	113.397
24	55.680	27.212	33.318	27.212	318.138	114.925	89.341	114.925
25	56.518	28.889	35.296	28.889	305.520	116.369	91.403	116.369
26	57.403	30.626	37.324	30.626	293.868	117.732	93.464	117.732
27	58.337	32.425	39.402	32.425	283.076	119.019	95.528	119.019
28	59.321	34.289	41.530	34.289	273.050	120.233	97.598	120.233
29	60.358	36.221	43.708	36.221	263.711	121.377	99.678	121.377
30	61.450	38.224	45.936	38.224	254.988	122.453	101.772	122.453
31	62.599	40.301	48.214	40.301	246.821	123.464	103.883	123.464
32	63.808	42.455	50.541	42.455	239.157	124.412	106.013	124.412
33	65.079	44.691	52.916	44.691	231.950	125.299	108.168	125.299
34	66.416	47.011	55.341	47.011	225.158	126.126	110.349	126.126
35	67.820	49.420	57.813	49.420	218.745	126.897	112.560	126.897
36	69.296	51.923	60.332	51.923	212.678	127.611	114.806	127.611
37	70.848	54.524	62.899	54.524	206.929	128.271	117.088	128.271
38	72.478	57.227	65.511	57.227	201.471	128.877	119.412	128.877
39	74.190	60.038	68.168	60.038	196.282	129.431	121.780	129.431
40	75.990	62.963	70.869	62.963	191.340	129.934	124.198	129.934
41	77.882	66.007	73.612	66.007	186.626	130.386	126.668	130.386
42	79.870	69.177	76.398	69.177	182.123	130.789	129.195	130.789
43	81.961	72.480	79.224	72.480	177.815	131.142	131.784	131.142
44	84.159	75.923	82.089	75.923	173.688	131.448	134.439	131.448
45	86.472	79.513	84.991	79.513	169.729	131.705	137.166	131.705
46	88.905	83.260	87.929	83.260	165.926	131.915	139.969	131.915
47	91.466	87.172	90.900	87.172	162.269	132.078	142.855	132.078
48	94.163	91.259	93.904	91.259	158.746	132.195	145.829	132.195
49	97.005	95.531	96.938	95.531	155.349	132.264	148.898	132.264
50	100.000	100.000	100.000	100.000	152.069	132.288	152.069	132.288

Table 6. Crossing over value (COV) and their standard errors based on the product method when one character pair is determined by a single factor difference and the other character pair by three duplicate factor differences-3 : 1 and 63 : 1 for F_2 or 1 : 1 and 7 : 1 for backcross (BC)

COV	Ratio of products, %				$\sqrt{n}$ × (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
%	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	0.029	0.762	0.636	0.762	399.978	28.062	56.379	28.062
2	0.118	1.549	1.293	1.549	399.913	39.374	79.467	39.374
3	0.265	2.360	1.973	2.360	399.805	47.846	97.007	47.846
4	0.471	3.199	2.677	3.199	399.653	54.817	111.649	54.817
5	0.736	4.064	3.405	4.064	399.458	60.811	124.424	60.811
6	1.062	4.957	4.159	4.957	399.219	66.098	135.863	66.098
7	1.447	5.880	4.939	5.880	398.937	70.841	146.282	70.841
8	1.893	6.832	5.748	6.832	398.612	75.147	155.889	75.147
9	2.400	7.816	6.585	7.816	398.243	79.090	164.828	79.090
10	2.970	8.832	7.453	8.832	397.830	82.725	173.204	82.725
11	3.602	9.881	8.352	9.881	397.374	86.094	181.096	86.094
12	4.297	10.965	9.284	10.965	396.874	89.229	188.568	89.229
13	5.057	12.085	10.251	12.085	396.330	22.157	195.669	92.157
14	5.882	13.243	11.255	13.243	395.742	94.899	202.439	94.899
15	6.774	14.439	12.296	14.439	395.110	97.472	208.911	97.472
16	7.734	15.675	13.376	15.675	394.434	99.892	215.114	99.892
17	8.763	16.952	14.499	16.952	393.714	102.170	221.071	102.170
18	9.863	18.274	15.665	18.274	392.950	104.319	226.802	104.319
19	11.035	19.640	16.876	19.640	392.142	106.346	232.325	106.346
20	12.281	21.053	18.136	21.053	391.288	108.261	237.654	108.261
21	13.602	22.514	19.446	22.514	390.391	110.070	242.805	110.070
22	15.001	24.027	20.809	24.027	389.448	111.781	247.787	111.781
23	16.480	25.592	22.228	25.592	388.460	113.397	252.612	113.397
24	18.041	27.212	23.705	27.212	387.427	114.925	257.288	114.925
25	19.686	28.889	25.245	28.889	386.349	116.369	261.825	116.369
26	21.418	30.626	26.849	30.626	385.225	117.732	266.230	117.732
27	23.240	32.425	28.522	32.425	384.055	119.019	270.509	119.019
28	25.154	34.289	30.267	34.289	382.839	120.233	274.669	120.233
29	27.164	36.221	32.090	36.221	381.577	121.377	278.715	121.377
30	29.272	38.224	33.993	38.224	380.268	122.453	282.652	122.453
31	31.484	40.301	35.981	40.301	378.913	123.464	286.486	123.464
32	33.801	42.455	38.061	42.455	377.510	124.412	290.219	124.412
33	36.229	44.691	40.236	44.691	376.060	125.299	293.857	125.299
34	38.771	47.011	42.514	47.011	374.562	126.126	297.403	126.126
35	41.432	49.420	44.899	49.420	373.016	126.897	300.860	126.897
31	44.217	51.923	47.400	51.923	371.421	127.611	304.231	127.611
37	47.132	54.524	50.023	54.524	369.777	128.271	307.518	128.271
38	50.182	57.227	52.776	57.227	378.083	128.877	310.726	128.877
39	53.372	60.038	55.668	60.038	366.340	129.431	313.856	129.431
40	56.710	62.963	58.709	62.963	364.546	129.934	316.910	129.934
41	60.202	66.007	61.907	66.007	362.701	130.386	319.891	130.386
42	63.856	69.177	65.275	69.177	360.804	130.789	322.800	130.789
43	67.679	72.480	68.824	72.480	358.856	131.142	325.639	131.142
44	71.681	75.923	72.567	75.923	356.854	131.448	328.410	131.448
45	75.870	79.513	76.518	79.513	354.799	131.705	331.115	131.705
41	80.256	83.260	80.694	83.260	352.690	131.915	333.755	131.915
47	84.851	87.172	85.110	87.172	350.525	132.078	336.332	132.078
48	89.664	91.259	89.786	91.259	348.305	132.195	338.846	132.195
49	94.709	95.531	94.741	95.531	346.028	132.264	341.300	132.264
50	100.000	100.000	100.000	100.000	343.693	132.288	343.693	132.288

Table 7. Crossing over value (COV) and their standard errors based on the product method when both character pairs are determined by two complementary factor differences-9 : 7 and 9 : 7 for F_2 or 1 : 3 and 1 : 3 for backcross (BC)

COV	Ratio of products, %				$\sqrt{n}\times$ (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
%	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	55.569	1.013	16.691	20.649	8606.730	28.109	80.852	158.344
2	55.609	2.051	17.624	21.318	4303.516	39.506	82.128	158.561
3	55.676	3.115	18.587	22.006	2869.177	48.087	83.411	158.763
4	55.769	4.207	19.582	22.715	2152.058	55.186	84.700	158.952
5	55.890	5.325	20.609	23.445	1721.826	61.325	85.999	159.126
6	56.037	6.473	21.668	24.197	1435.037	66.771	87.306	159.287
7	56.212	7.649	22.760	24.971	1230.215	71.686	88.623	159.433
8	56.415	8.854	23.884	25.769	1076.623	76.175	89.952	159.565
9	56.645	10.090	25.042	26.591	957.183	80.313	91.292	159.683
10	56.903	11.357	26.232	27.438	861.649	84.154	92.646	159.786
11	57.190	12.656	27.456	28.310	783.501	87.738	94.013	159.875
12	57.506	13.988	28.714	29.210	718.393	91.098	95.395	159.949
13	57.851	15.354	30.006	30.138	663.314	94.260	96.794	160.008
14	58.225	16.753	31.332	31.094	616.116	97.245	98.209	160.053
15	58.630	18.188	32.692	32.080	575.221	100.071	99.643	160.082
16	59.065	19.660	34.087	33.097	539.447	102.751	101.097	160.097
17	59.532	21.168	35.516	34.147	507.891	105.299	102.570	160.096
18	60.031	22.715	36.979	35.229	479.849	107.726	104.066	160.080
19	60.562	24.300	38.477	36.347	454.766	110.040	105.585	160.048
20	61.127	25.926	40.009	37.500	432.197	112.250	107.128	160.000
21	61.726	27.593	41.576	38.691	411.783	114.363	108.696	159.936
22	62.360	29.302	43.177	39.921	393.229	116.385	110.292	159.857
23	63.030	31.054	44.812	41.191	376.294	118.323	111.917	159.761
24	63.737	32.851	46.481	42.503	360.773	120.181	113.572	159.648
25	64.481	34.694	48.183	43.860	346.497	121.963	115.259	159.519
26	65.265	36.583	49.920	45.262	333.322	123.675	116.980	159.373
27	66.088	38.521	51.689	46.711	321.126	125.319	118.735	159.210
28	66.953	40.508	53.491	48.211	309.802	126.900	120.529	159.030
29	67.861	42.546	55.325	49.762	299.260	128.419	122.361	158.831
30	68.812	44.637	57.192	51.368	289.422	129.882	124.235	158.615
31	69.808	46.781	59.089	53.030	280.219	131.289	126.153	158.381
32	70.852	48.980	61.018	54.751	271.592	132.643	128.116	158.128
33	71.943	51.235	62.977	56.534	263.487	133.947	130.128	157.857
34	73.085	53.549	64.965	58.382	255.858	135.203	132.190	157.566
35	74.279	55.923	66.982	60.298	248.664	136.412	134.307	157.256
36	75.527	58.358	69.027	62.284	241.868	137.577	136.480	156.927
37	76.830	60.857	71.100	64.346	235.438	138.700	138.712	156.577
38	78.191	63.420	73.198	66.485	229.344	139.781	141.008	156.206
39	79.613	66.051	75.322	68.707	223.561	140.822	143.370	155.815
40	81.096	68.750	77.469	71.014	218.064	141.825	145.802	155.403
41	82.645	71.520	79.640	73.413	212.832	142.791	148.308	154.968
42	84.262	74.363	81.833	75.907	207.846	143.721	150.892	154.512
43	85.949	77.281	84.046	78.502	203.088	144.617	153.560	154.033
44	87.709	80.276	86.279	81.203	198.543	145.479	156.314	153.531
45	89.546	83.351	88.530	84.016	194.196	146.308	159.162	153.005
46	91.462	86.507	90.797	86.947	190.033	147.106	162.108	152.455
47	93.462	89.748	93.079	90.004	186.043	147.873	165.158	151.880
48	95.549	93.075	95.375	93.193	182.214	148.611	168.319	151.279
49	97.727	96.491	97.682	96.522	178.536	149.320	171.597	150.653
50	100.000	100.000	100.000	100.000	175.000	150.000	175.000	150.000

Table 8. Crossing over value (COV) and their standard errors based on the product method when one character pair is determined by two complementary factor differences and the other character pair by two duplicate factor differences-9 : 7 and 15 : 1 for F_2 and 1 : 3 and 3 : 1 for backcross (BC)

COV	Ratio of products, %				$\sqrt{n}\times$ (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
%	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	40.758	20.649	1.014	1.013	11267.08	158.344	32.594	28.109
2	40.809	21.318	2.057	2.051	5635.149	158.561	46.009	39.506
3	40.895	22.006	3.130	3.115	3758.548	158.763	56.253	48.087
4	41.015	22.715	4.233	4.207	2820.777	158.952	64.852	55.186
5	41.170	23.445	5.367	5.325	2258.535	159.126	72.403	61.325
6	41.360	24.197	6.533	6.473	1884.053	159.287	79.210	66.771
7	41.584	24.971	7.731	7.649	16 6.858	159.433	85.458	71.686
8	41.844	25.769	8.961	8.854	1416.714	159.565	91.265	76.175
9	42.140	26.591	10.226	10.090	1261.266	159.683	96.716	80.313
10	42.473	27.438	11.524	11.357	1137.100	159.786	101.872	84.154
11	42.841	28.310	12.858	12.656	1035.682	159.875	106.781	87.738
12	43.247	29.210	14.228	13.988	951.319	159.949	111.478	91.098
13	43.691	30.138	15.634	15.354	880.071	160.008	115.993	94.260
14	44.173	31.094	17.077	16.753	819.124	160.053	120.351	97.245
15	44.695	32.080	18.559	18.188	766.413	160.082	124.572	100.071
16	45.256	33.097	20.079	19.660	720.389	160.097	128.673	102.751
17	45.858	34.147	21.639	21.168	679.869	160.096	132.669	105.299
18	46.501	35.229	23.239	22.715	643.930	160.080	136.572	107.726
19	47.187	36.347	24.881	24.300	611.845	160.048	140.394	110.040
20	47.917	37.500	26.564	25.926	583.032	160.000	144.145	112.250
21	48.691	38.691	28.290	27.593	557.018	159.936	147.834	114.363
22	49.511	39.921	30.060	29.302	533.420	159.857	151.470	116.385
23	50.379	41.191	31.874	31.054	511.916	159.761	155.060	118.323
24	51.295	42.503	33.733	32.851	492.242	159.648	158.612	120.181
25	52.261	43.860	35.638	34.694	474.175	159.519	162.131	121.963
26	53.279	45.262	37.590	36.583	457.524	159.373	165.624	123.675
27	54.350	46.711	39.589	38.521	442.129	159.210	169.097	125.319
28	55.476	48.211	41.636	40.508	427.851	159.030	172.556	126.900
29	56.660	49.762	43.732	42.546	414.572	158.831	176.006	128.419
30	57.902	51.368	45.878	44.637	402.188	158.615	179.452	129.882
31	59.206	53.030	48.074	46.781	390.609	158.381	182.901	131.289
32	60.573	54.751	50.321	48.980	379.756	158.128	186.356	132.643
33	62.007	56.534	52.620	51.235	369.559	157.857	189.823	133.947
34	63.509	58.382	54.971	53.549	359.957	157.566	193.308	135.203
35	65.083	60.298	57.375	55.923	350.896	157.256	196.815	136.412
36	66.732	62.284	59.833	58.358	342.329	156.927	200.350	137.577
37	68.459	64.346	62.344	60.857	334.210	156.577	203.918	138.700
38	70.267	66.485	64.910	63.420	326.503	156.206	207.525	139.781
39	72.161	68.707	67.530	66.051	319.171	155.815	211.176	140.822
40	74.144	71.014	70.206	68.750	312.185	155.403	214.878	141.825
41	76.220	73.413	72.937	71.520	305.515	154.968	218.636	142.791
42	78.394	75.907	75.723	74.363	299.136	154.512	222.457	143.721
43	80.671	78.502	78.565	77.281	293.025	154.033	226.347	144.617
44	83.057	81.203	81.462	80.276	287.161	153.531	230.314	145.479
45	85.557	84.016	84.415	83.351	281.524	153.005	234.365	146.308
46	88.177	86.947	87.423	86.507	276.096	152.455	238.507	147.106
47	90.924	90.004	90.487	89.748	270.861	151.880	242.750	147.873
48	93.805	93.193	93.604	93.075	265.805	151.279	247.103	148.611
49	96.827	96.522	96.775	96.491	260.914	150.653	251.574	149.320
50	100.000	100.000	100.000	100.000	256.174	150.000	256.174	150.000

Table 9. Crossing over value (COV) and their standard errors based on the product method when one character pair is determined by two complementary factor differences and the other character pair by two inhibiting factor differences–9 : 7 and 3 : 13 for F_2 or 1 : 3 and 1 : 3 for backcross (BC)

COV	Ratio of products, %				$\sqrt{n}\times$ (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
%	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	73.342	1.013	37.132	20.649	20769.51	28.109	187.539	158.344
2	73.370	2.051	38.275	21.318	10384.76	39.506	190.458	158.561
3	73.415	3.115	39.429	22.006	6923.191	48.087	193.399	158.763
4	73.479	4.207	40.593	22.715	5192.405	55.186	196.362	158.952
5	73.560	5.325	41.768	23.445	4153.935	61.325	199.350	159.126
6	73.660	6.473	42.953	24.197	3461.624	66.771	202.365	159.287
7	73.779	7.649	44.149	24.971	2967.116	71.686	205.409	159.433
8	73.916	8.854	45.354	25.769	2596.236	76.175	208.486	159.565
9	74.071	10.090	46.568	26.591	2307.773	80.313	211.596	159.683
10	74.246	11.357	47.792	27.438	2077.002	84.154	214.743	159.786
11	74.439	12.656	49.025	28.310	1888.188	87.738	217.929	159.875
12	74.651	13.988	50.266	29.210	1730.842	91.098	221.157	159.949
13	74.882	15.354	51.516	30.138	1597.702	94.260	224.428	160.008
14	75.132	16.753	52.774	31.094	1483.579	97.245	227.746	160.053
15	75.402	18.188	54.040	32.080	1384.670	100.071	231.113	160.082
16	75.691	19.660	55.313	33.097	1298.123	102.751	234.533	160.097
17	76.001	21.168	56.594	34.147	1221.754	105.299	238.007	160.096
18	76.330	22.715	57.881	35.229	1153.867	107.726	241.539	160.080
19	76.680	24.300	59.175	36.347	1093.123	110.040	245.132	160.048
20	77.051	25.926	60.474	37.500	1038.449	112.250	248.790	160.000
21	77.443	27.593	61.780	38.691	988.979	114.363	252.515	159.936
22	77.856	29.302	63.091	39.921	944.001	116.385	256.311	159.857
23	78.290	31.054	64.406	41.191	902.929	118.323	260.181	159.761
24	78.746	32.851	65.726	42.503	865.275	120.181	264.130	159.648
25	79.225	34.694	67.051	43.860	830.628	121.963	268.162	159.519
26	79.726	36.583	68.378	45.262	798.640	123.675	272.280	159.373
27	80.251	38.521	69.709	46.711	769.016	125.319	276.489	159.210
28	80.799	40.508	71.043	48.211	741.502	126.900	280.793	159.030
29	81.371	42.546	72.379	49.762	715.879	128.419	285.197	158.831
30	81.967	44.637	73.717	51.368	691.958	129.882	289.707	158.615
31	82.588	46.781	75.056	53.030	669.573	131.289	294.327	158.381
32	83.235	48.980	76.395	54.751	648.579	132.643	299.064	158.128
33	83.907	51.235	77.735	56.534	628.851	133.947	303.922	157.857
34	84.607	53.549	79.075	58.382	610.275	135.203	308.909	157.566
35	85.333	55.923	80.414	60.298	592.752	136.412	314.030	157.256
36	86.087	58.358	81.751	62.284	576.195	137.577	319.293	156.927
37	86.870	60.857	83.086	64.346	560.523	138.700	324.706	156.577
38	87.682	63.420	84.419	66.485	545.668	139.781	330.276	156.206
39	88.523	66.051	85.749	68.707	531.566	140.822	336.011	155.815
40	89.396	68.750	87.075	71.014	518.159	141.825	341.921	155.403
41	90.299	71.520	88.397	73.413	505.396	142.791	348.014	154.968
42	91.235	74.363	89.714	75.907	493.231	143.721	354.302	154.512
43	92.204	77.281	91.026	78.502	481.621	144.617	360.794	154.033
44	93.208	80.276	92.331	81.203	470.529	145.479	367.503	153.531
45	94.246	83.351	93.630	84.016	459.918	146.308	374.441	153.005
46	95.320	86.507	94.921	86.947	449.758	147.106	381.622	152.455
47	96.432	89.748	96.204	90.004	440.018	147.873	389.058	151.880
48	97.581	93.075	97.479	93.193	430.673	148.611	396.767	151.279
49	98.770	96.491	98.745	96.522	421.697	149.320	404.764	150.653
50	100.000	100.000	100.000	100.000	413.068	150.000	413.068	150.000

Table 10. Crossing over value (COV) and their standard errors based on the product method when one character pair is determined by two complementary factor differences and the other character pair by three complementary factor differences-9 : 7 and 27 : 37 for F_2 or 1 : 3 and 1 : 7 for backcross (BC)

COV	Ratio of products, %				$\sqrt{n}\times$ (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
%	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	64.456	1.261	25.745	27.942	11587.07	39.830	108.335	256.948
2	64.490	2.543	26.807	28.627	5793.598	56.090	109.918	256.970
3	64.547	3.847	27.892	29.329	3862.468	68.406	111.512	256.971
4	64.627	5.174	28.999	30.049	2896.923	78.655	113.121	256.950
5	64.729	6.524	30.130	30.786	2317.612	87.568	114.743	256.907
6	64.855	7.897	31.283	31.541	1931.418	95.522	116.382	256.842
7	65.004	9.293	32.459	32.316	1655.577	102.741	118.037	256.755
8	65.177	10.714	33.658	33.110	1448.705	109.373	119.711	256.646
9	65.372	12.160	34.880	33.925	1287.813	115.520	121.404	256.515
10	65.592	13.630	36.124	34.760	1159.107	121.258	123.119	256.361
11	65.835	15.126	37.390	35.618	1053.807	126.643	124.855	256.186
12	66.103	16.648	38.679	36.497	966.064	131.720	126.615	255.987
13	66.395	18.197	39.990	37.400	891.824	136.524	128.400	255.766
14	66.712	19.773	41.323	38.327	828.194	141.085	130.212	255.523
15	67.054	21.376	42.677	39.279	773.051	145.426	132.051	255.256
16	67.421	23.007	44.053	40.257	724.805	149.567	133.920	254.966
17	67.815	24.667	45.449	41.261	682.237	153.526	135.819	254.652
18	68.234	26.356	46.867	42.293	644.401	157.317	137.752	254.315
19	68.680	28.075	48.305	43.354	610.550	160.952	139.718	253.955
20	69.154	29.825	49.763	44.444	580.086	164.444	141.721	253.570
21	69.655	31.605	51.241	45.566	552.524	167.801	143.762	253.161
22	70.184	33.417	52.739	46.720	527.468	171.033	145.842	252.727
23	70.742	35.261	54.255	47.907	504.592	174.147	147.964	252.269
24	71.330	37.137	55.790	49.129	483.622	177.150	150.131	251.786
25	71.947	39.048	57.343	50.388	464.330	180.048	152.343	251.277
26	72.595	40.992	58.914	51.684	446.522	182.847	154.604	250.743
27	73.275	42.971	60.501	53.019	430.032	185.551	156.916	250.182
28	73.987	44.986	62.105	54.395	414.719	188.167	159.281	249.596
29	74.732	47.037	63.724	55.813	400.461	190.697	161.702	248.982
30	75.511	49.126	65.359	57.276	387.153	193.146	164.182	248.342
31	76.325	51.252	67.008	58.786	374.701	195.517	166.723	247.675
32	77.174	53.416	68.671	60.344	363.026	197.814	169.330	246.979
33	78.060	55.620	70.348	61.952	352.056	200.040	172.004	246.256
34	78.984	57.864	72.036	63.614	341.729	202.198	174.751	245.504
35	79.947	60.149	73.736	65.330	331.990	204.289	177.572	244.722
33	80.949	62.477	75.447	67.105	322.790	206.318	180.473	243.912
67	81.993	64.846	77.168	68.941	314.083	208.285	183.457	243.071
38	83.080	67.260	78.897	70.840	305.832	210.193	186.528	242.199
39	84.210	69.718	80.635	72.806	298.001	212.045	189.692	241.297
40	85.385	72.222	82.380	74.843	290.558	213.842	192.954	240.362
41	86.608	74.773	84.131	76.953	283.474	215.585	196.318	239.396
42	87.878	77.371	85.888	79.141	276.723	217.277	199.790	238.396
43	89.199	80.017	87.648	81.410	270.283	218.919	203.376	237.363
44	90.571	82.714	89.412	83.766	264.130	220.512	207.084	236.296
45	91.997	85.461	91.178	86.213	258.247	222.059	210.919	235.193
46	93.479	88.260	92.945	88.755	252.615	223.560	214.889	234.055
47	95.017	91.113	94.712	91.399	247.217	225.016	219.002	232.880
48	96.616	94.019	96.478	94.150	242.039	226.429	223.267	231.668
49	98.276	96.981	98.241	97.015	237.068	227.799	227.693	230.418
50	100.000	100.000	100.000	100.000	232.289	229.129	232.289	229.129

Table 11. Crossing over value (COV) and their standard errors based on the product method when one character pair is determined by two complementary factor differences and the other character pair by three duplicate factor differences–9 : 7 and 63 : 1 for F_2 or 1 : 3 and 7 : 1 for backcross (BC)

COV	Ratio of products, %				$\sqrt{n}\times$ (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
%	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	42.359	27.942	1.137	1.261	22958.08	256.948	65.290	39.830
2	42.411	28.627	2.300	2.543	11482.44	256.970	92.299	56.090
3	42.497	29.329	3.489	3.847	7658.732	256.971	113.009	68.406
4	42.617	30.049	4.703	5.174	5747.998	256.950	130.461	78.655
5	42.772	30.786	5.945	6.524	4602.448	256.907	145.837	87.568
6	42.962	31.541	7.214	7.897	3839.480	256.842	159.744	95.522
7	43.187	32.316	8.512	9.293	3295.124	256.755	172.544	102.741
8	43.447	33.110	9.838	10.714	2887.390	256.646	184.472	109.373
9	43.743	33.925	11.194	12.160	2570.729	256.515	195.695	115.520
10	44.074	34.760	12.579	13.630	2317.810	256.361	206.334	121.258
11	44.443	35.618	13.995	15.126	2111.240	256.186	216.479	126.643
12	44.848	36.497	15.443	16.648	1939.423	255.987	226.203	131.720
13	45.291	37.400	16.922	18.197	1794.329	255.766	235.564	136.524
14	45.772	38.327	18.434	19.773	1670.223	255.523	244.609	141.085
15	46.291	39.279	19.979	21.376	1562.899	255.256	253.377	145.426
16	46.850	40.257	21.559	23.007	1469.201	254.966	261.903	149.567
17	47.449	41.261	23.172	24.667	1386.714	254.652	270.215	153.526
18	48.089	42.293	24.822	26.356	1313.563	254.315	278.338	157.317
19	48.771	43.354	26.507	28.075	1248.264	253.955	286.295	160.952
20	49.495	44.444	28.229	29.825	1189.630	253.570	294.105	164.444
21	50.263	45.566	29.988	31.605	1136.702	253.161	301.786	167.801
22	51.076	46.720	31.786	33.417	1088.691	252.727	309.356	171.033
23	51.935	47.907	33.622	35.261	1044.950	252.269	316.828	174.147
24	52.841	49.129	35.498	37.137	1004.934	251.786	324.216	177.150
25	53.796	50.388	37.414	39.048	968.191	251.277	331.535	180.048
26	54.800	51.684	39.371	40.992	934.333	250.743	338.796	182.847
27	55.857	53.019	41.370	42.971	903.032	250.182	346.011	185.551
28	56.966	54.395	43.411	44.986	874.007	249.596	353.191	188.167
29	58.130	55.813	45.494	47.037	847.015	248.982	360.347	190.697
30	59.351	57.276	47.622	49.126	821.844	248.342	367.491	193.146
31	60.630	58.786	49.793	51.252	798.311	247.675	374.633	195.517
32	61.970	60.344	52.009	53.416	776.256	246.979	381.782	197.814
33	63.373	61.952	54.271	55.620	755.536	246.256	388.951	200.040
34	64.842	63.614	56.579	57.864	736.026	245.504	396.148	202.198
35	66.378	65.330	58.933	60.149	717.616	244.722	403.385	204.289
36	67.985	67.105	61.333	62.477	700.208	243.912	410.673	206.318
37	69.666	68.941	63.782	64.846	683.712	243.071	418.022	208.285
38	71.424	70.840	66.278	67.260	668.051	242.199	425.445	210.193
39	73.261	72.806	68.821	69.718	653.154	241.297	432.951	212.045
40	75.182	74.843	71.414	72.222	638.956	240.362	440.554	213.842
41	77.191	76.953	74.055	74.773	625.400	239.396	448.266	215.585
42	79.291	79.141	76.744	77.371	612.434	238.396	456.101	217.277
43	81.488	81.410	79.482	80.017	600.010	237.363	464.071	218.919
44	83.785	83.766	82.269	82.714	588.084	236.296	472.192	220.512
45	86.188	86.213	85.105	85.461	576.618	235.193	480.478	222.059
46	88.702	88.755	87.989	88.260	565.574	234.055	488.947	223.560
47	91.334	91.399	90.921	91.113	554.920	232.880	497.614	225.016
48	94.090	94.150	93.900	94.019	544.624	231.663	506.499	226.429
49	96.976	97.015	96.927	96.981	534.660	230.418	515.620	227.799
50	100.000	100.000	100.000	100.000	525.000	229.129	525.000	229.129

Table 12. Crossing over value (COV) and their standard errors based on the product method when both character pairs are determined by two duplicate factor differences-15 : 1 and 15 : 1 for F_2 or 3 : 1 and 3 : 1 for backcross (BC)

COV	Ratio of products, %				$\sqrt{n}$ × (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
%	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	0.035	1.013	16.330	20.648	399.990	28.109	309.873	158.344
2	0.140	2.051	16.889	21.318	399.959	39.506	311.514	158.561
3	0.315	3.115	17.467	22.006	399.907	48.087	313.144	158.763
4	0.560	4.207	18.065	22.715	399.834	55.186	314.761	158.952
5	0.876	5.325	18.683	23.445	399.741	61.325	316.367	159.126
6	1.262	6.473	19.323	24.197	399.627	66.771	317.962	159.287
7	1.719	7.649	19.984	24.971	399.493	71.686	319.544	159.433
8	2.247	8.854	20.670	25.769	399.338	76.175	321.115	159.565
9	2.847	10.090	21.379	26.591	399.162	80.313	322.673	159.683
10	3.518	11.357	22.114	27.438	398.966	84.154	324.219	159.786
11	4.262	12.656	22.876	28.310	398.749	87.738	325.754	159.875
12	5.078	13.988	23.665	29.210	398.512	91.098	327.276	159.949
13	5.967	15.354	24.483	30.138	398.254	94.260	328.786	160.008
14	6.930	16.753	25.331	31.094	397.976	97.245	330.283	160.053
15	7.968	18.188	26.212	32.080	397.677	100.071	331.768	160.082
16	9.080	19.660	27.125	33.097	397.359	102.751	333.240	160.097
17	10.268	21.168	28.073	34.147	397.019	105.299	334.700	160.096
18	11.533	22.715	29.058	35.229	396.660	107.726	336.146	160.080
19	12.874	24.300	30.081	36.347	396.281	110.040	337.580	160.048
20	14.294	25.926	31.144	37.500	395.881	112.250	339.001	160.000
21	15.793	27.593	32.250	38.691	395.462	114.363	340.409	159.936
22	17.373	29.302	33.399	39.921	395.022	116.385	341.803	159.857
23	19.033	31.054	34.596	41.191	394.563	118.323	343.185	159.761
24	20.775	32.851	35.842	42.503	394.084	120.181	344.552	159.648
25	22.600	34.694	37.139	43.860	393.585	121.963	345.907	159.519
26	24.510	36.583	38.491	45.262	393.067	123.675	347.247	159.373
27	26.506	38.521	39.901	46.711	392.529	125.319	348.574	159.210
28	28.588	40.508	41.372	48.211	391.972	126.900	349.887	159.030
29	30.759	42.546	42.906	49.762	391.395	128.419	351.186	158.831
30	33.020	44.637	44.509	51.368	390.799	129.882	352.471	158.615
31	35.372	46.781	46.183	53.030	390.184	131.289	353.741	158.381
32	37.817	48.980	47.934	54.751	389.550	132.643	354.997	158.128
33	40.357	51.235	49.765	56.534	388.897	133.947	356.239	157.857
34	42.993	53.549	51.681	58.382	388.225	135.203	357.466	157.566
35	45.727	55.923	53.688	60.298	387.534	136.412	358.678	157.256
36	48.561	58.358	55.792	62.284	386.825	137.577	359.875	156.927
37	51.497	60.857	57.998	64.346	386.097	138.700	361.057	156.577
38	54.537	63.420	60.314	66.485	385.351	139.781	362.224	156.206
39	57.683	66.051	62.746	68.707	384.586	140.822	363.376	155.815
40	60.938	68.750	65.302	71.014	383.803	141.825	364.513	155.403
41	64.303	71.520	67.991	73.413	383.002	142.791	365.633	154.968
42	67.781	74.363	70.822	75.907	382.183	143.721	366.739	154.512
43	71.375	77.281	73.805	78.502	381.347	144.617	367.828	154.033
44	75.087	80.276	76.951	81.203	380.492	145.479	368.901	153.531
45	78.920	83.351	80.272	84.016	379.620	146.308	369.959	153.005
46	82.876	86.507	83.780	86.947	378.731	147.106	371.000	152.455
47	86.959	89.748	87.491	90.004	377.824	147.873	372.025	151.880
48	91.172	93.075	91.419	93.193	376.899	148.611	373.033	151.279
49	95.518	96.491	95.583	96.522	375.958	149.320	374.025	150.653
50	100.000	100.000	100.000	100.000	375.000	150.000	375.000	150.000

Table 13. Crossing over value (COV) and their standard errors based on the product method when one character pair is determined by two duplicate factor differences and the other character pair by two inhibiting factor differences-15 : 1 and 3 : 13 for F_2 or 3 : 1 and 1 : 3 for backcross (BC)

COV	Ratio of products, %				$\sqrt{n}$ × (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
%	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	67.357	20.649	2.004	1.013	33278.62	158.344	56.796	28.109
2	67.386	21.318	4.016	2.051	16637.78	158.561	80.655	39.506
3	67.435	22.006	6.036	3.115	11090.16	158.763	99.205	48.087
4	67.503	22.715	8.062	4.207	8315.845	158.952	115.056	55.186
5	67.591	23.445	10.096	5.325	6650.844	159.126	129.219	61.325
6	67.698	24.197	12.136	6.473	5540.502	159.287	142.212	66.771
7	67.826	24.971	14.181	7.649	4747.105	159.433	154.343	71.686
8	67.974	25.769	16.232	8.854	4151.799	159.565	165.813	76.175
9	68.142	26.591	18.288	10.090	3688.551	159.683	176.762	80.313
10	68.330	27.438	20.349	11.357	3317.742	159.786	187.294	84.154
11	68.539	28.310	22.413	12.656	3014.161	159.875	197.486	87.738
12	68.769	29.210	24.481	13.988	2760.998	159.949	207.401	91.098
13	69.020	30.138	26.552	15.354	2546.618	160.008	217.088	94.260
14	69.293	31.094	28.626	16.753	2362.708	160.053	226.588	97.245
15	69.588	32.080	30.701	18.188	2203.171	160.082	235.936	100.071
16	69.905	33.097	32.778	19.660	2063.438	160.097	245.162	102.751
17	70.245	34.147	34.856	21.168	1940.011	160.096	254.290	105.299
18	70.608	35.229	36.934	22.712	1830.170	160.080	263.345	107.726
19	70.994	36.347	39.012	24.300	1731.770	160.048	272.346	110.040
20	71.405	37.500	41.090	25.926	1643.092	160.000	281.312	112.250
21	71.841	38.691	43.166	27.593	1562.745	159.936	290.261	114.363
22	72.302	39.921	45.240	29.302	1489.592	159.857	299.207	116.385
23	72.789	41.191	47.312	31.054	1422.692	159.761	308.166	118.323
24	73.303	42.503	49.381	32.851	1361.262	159.648	317.152	120.181
25	73.844	43.860	51.446	34.694	1304.644	159.519	326.178	121.963
26	74.414	45.262	53.507	36.583	1252.281	159.373	335.258	123.675
27	75.013	46.711	55.563	38.521	1203.698	159.210	344.404	125.319
28	75.641	48.211	57.614	40.508	1158.488	159.030	353.629	126.900
29	76.301	49.762	59.658	42.546	1116.300	158.831	362.946	128.419
30	76.993	51.368	61.696	44.637	1076.831	158.615	372.366	129.882
31	77.718	53.030	63.726	46.781	1039.814	158.381	381.902	131.289
32	78.477	54.751	65.748	48.980	1005.018	158.128	391.567	132.643
33	79.272	56.534	67.762	51.235	972.240	157.857	401.374	133.947
34	80.104	58.382	69.766	53.549	941.298	157.566	411.335	135.203
35	80.975	60.298	71.760	55.923	912.034	157.256	421.465	136.412
36	81.885	62.284	73.743	58.358	884.305	156.927	431.776	137.577
37	82.837	64.346	75.715	60.857	857.985	156.577	442.284	138.700
38	83.832	66.485	77.675	63.420	832.961	156.206	453.003	139.781
39	84.872	68.707	79.622	66.051	809.129	155.815	463.948	140.822
40	85.960	71.014	81.556	68.750	786.400	155.403	475.136	141.825
41	87.097	73.413	83.476	71.520	764.688	154.968	486.585	142.791
42	88.286	75.907	85.380	74.363	743.921	154.512	498.311	143.721
43	89.529	78.502	87.269	77.281	724.028	154.033	510.334	144.617
44	90.829	81.203	89.142	80.276	704.948	153.531	522.674	145.479
45	92.188	84.016	90.998	83.351	686.624	153.005	535.353	146.308
46	93.611	86.947	92.837	86.507	669.005	152.455	548.392	147.106
47	95.099	90.004	94.657	89.748	652.041	151.880	561.817	147.873
48	96.658	93.193	96.458	93.075	635.691	151.279	575.652	148.611
49	98.290	96.522	98.239	96.491	619.913	150.653	589.927	149.320
50	100.000	100.000	100.000	100.000	604.669	150.000	604.669	150.000

Table 14. Crossing over value (COV) and their standard errors based on the product method when one character pair is determined by two duplicate factor differences and the other character pair by three complementary factor differences–15 : 1 and 27 : 37 for F_2 or 3 : 1 and 1 : 7 for backcross (BC)

COV	Ratio of products, %				$\sqrt{n}\times$ (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
%	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	54.623	27.942	1.388	1.261	17070.23	256.948	37.728	39.830
2	54.663	28.627	2.801	2.543	8535.458	256.970	53.386	56.090
3	55.730	29.329	4.241	3.847	5690.686	256.971	65.430	68.406
4	54.824	30.049	5.706	5.174	4268.412	256.950	75.615	78.655
5	54.944	30.786	7.198	6.524	3415.136	256.907	84.622	87.568
6	55.092	31.541	8.716	7.897	2846.356	256.842	92.802	95.522
7	55.266	32.316	10.260	9.293	2440.144	256.755	100.363	102.741
8	55.469	33.110	11.831	10.714	2135.535	256.646	107.442	109.373
9	55.699	33.925	13.429	12.160	1898.659	256.515	114.135	115.520
10	55.957	34.760	15.053	13.630	1709.194	256.361	120.512	121.258
11	56.244	35.618	16.705	15.126	1554.207	256.186	126.626	126.643
12	56.560	36.497	18.383	16.648	1425.078	255.987	132.519	131.720
13	56.904	37.400	20.088	18.197	1315.836	255.766	138.225	136.524
14	57.279	38.327	21.821	19.773	1222.217	255.523	143.773	141.085
15	57.684	39.279	23.580	21.376	1141.096	255.256	149.184	145.426
16	58.119	40.257	25.366	23.007	1070.126	254.966	154.480	149.567
17	58.586	41.261	27.179	24.667	1007.513	254.652	159.677	153.526
18	59.085	42.293	29.019	26.356	951.863	254.315	164.791	157.317
19	59.617	43.354	30.886	28.075	902.074	253.955	169.835	160.952
20	60.182	44.444	32.780	29.825	857.265	253.570	174.821	164.444
21	60.782	45.566	34.700	31.605	816.721	253.161	179.760	167.801
22	61.417	46.720	36.646	33.417	779.859	252.727	184.663	171.033
23	62.088	47.907	38.619	35.261	746.197	252.269	189.539	174.147
24	62.796	49.129	40.617	37.137	715.331	251.786	194.396	177.150
25	63.543	50.388	42.641	39.048	686.925	251.277	199.244	180.048
26	64.328	51.684	44.691	40.992	660.692	250.743	204.090	182.847
27	65.155	53.019	46.765	42.971	636.388	250.182	208.942	185.551
28	66.024	54.395	48.864	44.986	613.805	249.596	213.807	188.167
29	66.936	55.813	50.988	47.037	592.762	248.982	218.693	190.697
30	67.893	57.276	53.135	49.126	573.102	248.342	223.607	193.146
31	68.896	58.786	55.306	51.252	554.690	247.675	228.556	195.517
32	69.948	60.344	57.500	53.416	537.407	246.979	233.548	197.814
33	71.050	61.952	59.715	55.620	521.146	246.256	238.590	200.040
34	72.204	63.614	61.953	57.864	505.817	245.504	243.688	202.198
35	73.412	65.330	64.211	60.149	491.336	244.722	248.851	204.289
36	74.676	67.105	66.490	62.477	477.630	243.912	254.086	206.318
37	75.999	68.941	68.789	64.846	464.635	243.071	259.402	208.285
38	77.383	70.840	71.106	67.260	452.292	242.199	264.805	210.193
39	78.831	72.806	73.440	69.718	440.548	241.297	270.305	212.045
40	80.346	74.843	75.792	72.222	429.356	240.362	275.911	213.842
41	81.932	76.953	78.160	74.773	418.673	239.396	281.630	215.585
42	83.590	79.141	80.543	77.371	408.460	238.396	287.474	217.277
43	85.326	81.410	82.939	80.017	398.683	237.363	293.453	218.919
44	87.143	83.766	85.349	82.714	389.308	236.296	299.575	220.512
45	89.044	86.213	87.769	85.461	380.307	235.193	305.854	222.059
46	91.036	88.755	90.200	88.260	371.653	234.055	312.301	223.560
47	93.122	91.399	92.640	91.113	363.321	232.880	318.929	225.016
48	95.307	94.150	95.088	94.019	355.288	231.668	325.751	226.429
49	97.598	97.015	97.542	96.981	347.533	230.418	332.782	227.799
50	100.000	100.000	100.000	100.000	340.037	229.129	340.037	229.129

Table 15. Crossing over value (COV) and their standard errors based on the product method when one character pair is determined by two duplicate factor differences and the other character pair by three duplicate factor differences-15 : 1 and 63 : 1 for F_2 or 3 : 1 and 7 : 1 for backcross (BC)

COV %	Ratio of products, %				$\sqrt{n}$ × (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	0.037	1.261	19.529	27.942	799.987	39.830	677.592	256.948
2	0.148	2.543	20.087	28.627	799.949	56.090	780.051	256.970
3	0.332	3.847	20.664	29.329	799.886	68.406	682.484	256.971
4	0.590	5.174	21.259	30.049	799.797	78.655	684.891	256.950
5	0.923	6.524	21.873	30.786	799.683	87.568	687.271	256.907
6	1.329	7.897	22.507	31.541	799.544	95.522	688.626	256.842
7	1.810	9.293	23.162	32.316	799.379	102.741	691.954	256.755
8	2.365	10.714	23.839	33.110	799.189	109.373	694.257	256.646
9	2.995	12.160	24.538	33.952	798.974	115.520	696.535	256.515
10	3.699	13.630	25.262	34.760	798.733	121.258	698.786	256.361
11	4.479	15.126	26.010	35.618	798.468	126.643	701.013	256.186
12	5.334	16.648	26.785	36.497	798.176	131.720	703.214	255.987
13	6.265	18.197	27.586	37.400	797.860	136.524	703.389	255.766
14	7.273	19.773	28.416	38.327	797.518	141.085	707.540	255.523
15	8.356	21.376	29.276	39.279	797.151	145.426	709.666	255.256
16	9.517	23.007	30.168	40.257	796.759	149.567	711.766	254.966
17	10.755	24.667	31.092	41.261	796.341	153.526	713.841	254.652
18	12.071	26.356	32.050	42.293	795.899	157.317	715.892	254.315
19	13.466	28.075	33.045	43.354	795.431	160.952	717.918	253.957
20	14.939	29.825	34.077	44.444	794.938	164.444	719.919	253.570
21	16.492	31.605	35.149	45.566	794.419	167.801	721.895	253.161
22	18.125	33.417	36.263	46.720	793.876	171.033	723.846	252.727
23	19.838	35.261	37.422	47.907	793.308	174.147	725.773	252.269
24	21.633	37.137	38.626	49.129	792.714	177.150	727.675	251.786
25	23.511	39.048	39.880	50.388	792.095	180.048	729.552	251.277
26	25.471	40.992	41.185	51.684	791.451	182.847	731.405	250.743
27	27.515	42.971	42.544	53.019	790.782	185.551	733.233	250.182
28	29.643	44.986	43.961	54.395	790.088	188.167	735.037	249.596
29	31.857	47.037	45.438	55.813	789.369	190.697	736.816	248.982
30	34.156	49.126	46.980	57.276	788.625	193.146	738.570	248.342
31	36.543	51.252	48.589	58.786	787.856	195.517	740.300	247.675
32	39.019	53.416	50.270	60.344	787.062	197.814	742.006	246.979
33	41.583	55.620	52.028	61.952	786.243	200.040	743.687	246.256
34	44.237	57.864	53.866	63.614	785.399	202.198	745.344	245.504
35	46.983	60.149	55.791	65.330	784.530	204.289	746.976	244.722
36	49.821	62.477	57.806	67.105	783.636	206.318	748.584	243.912
37	52.753	64.846	59.919	68.941	782.718	208.285	750.167	243.071
38	55.779	67.260	62.135	70.840	781.774	210.193	751.726	242.199
39	58.901	69.718	64.461	72.806	780.806	212.045	753.260	241.297
40	62.121	72.222	66.905	74.843	779.813	213.842	754.770	240.362
41	65.440	74.773	69.475	76.953	778.795	215.585	756.255	239.396
42	68.858	77.371	72.179	79.141	777.752	217.277	757.716	238.396
43	72.379	80.017	75.027	81.410	776.685	218.919	759.153	237.363
44	76.002	82.714	78.030	83.766	775.592	220.512	760.565	236.296
45	79.730	85.461	81.198	86.213	774.476	222.059	761.952	235.193
46	83.565	88.260	84.544	88.755	773.334	223.560	763.315	234.055
47	87.507	91.113	88.082	91.399	772.168	225.016	764.653	232.880
48	91.559	94.019	91.826	94.150	770.977	226.429	765.967	231.668
49	95.723	96.981	95.792	97.015	769.761	227.799	767.257	230.418
50	100.000	100.000	100.000	100.000	768.521	229.129	768.521	229.129

Table 16. Crossing over value (COV) and their standard errors based on the product method when both character pairs are determined by two inhibiting factor differences-3 : 13 and 3 : 13 for F_2 or 1 : 3 and 1 : 3 for backcross (BC)

COV	Ratio of products, %				$\sqrt{n}$ × (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
%	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	84.006	1.013	63.519	20.649	47016.98	28.109	530.276	158.344
2	84.024	2.051	64.251	21.318	23509.61	39.506	534.877	158.561
3	84.055	3.115	64.986	22.006	15674.32	48.087	539.570	158.763
4	84.097	3.207	65.724	22.715	11757.05	55.186	544.358	158.952
5	84.152	5.325	66.464	23.445	9406.988	61.325	549.245	159.126
6	84.219	6.473	67.208	24.197	7840.527	66.771	554.234	159.287
7	84.298	7.649	67.954	24.971	6721.839	71.686	559.328	159.433
8	84.390	8.854	68.703	25.769	5883.008	76.175	564.532	159.565
9	84.493	10.090	69.454	26.591	5230.749	80.313	569.849	159.683
10	84.609	11.357	70.207	27.438	4709.089	84.154	575.283	159.786
11	84.737	12.656	70.962	28.310	4282.409	87.738	580.839	159.875
12	84.878	13.988	71.719	29.210	3926.965	91.098	586.520	159.949
13	85.031	15.354	72.478	30.138	3626.317	94.260	592.332	160.008
14	85.196	16.753	73.239	31.094	3368.722	97.245	598.279	160.053
15	85.374	18.188	74.001	32.080	3145.570	100.071	604.366	160.082
16	85.565	19.660	74.764	33.097	2950.401	102.751	610.599	160.097
17	85.767	21.168	75.529	34.147	2778.277	105.299	616.984	160.096
18	85.983	22.715	76.294	35.229	2625.357	107.726	623.525	160.080
19	86.211	24.300	77.060	36.347	2488.608	110.040	630.229	160.048
20	86.452	25.926	77.827	37.500	2365.603	112.250	637.103	160.000
21	86.705	27.593	78.594	38.691	2254.380	114.363	644.153	159.936
22	86.972	29.302	79.361	39.921	2153.330	116.385	651.386	159.857
23	87.251	31.054	80.129	41.191	2061.127	118.323	658 811	159.761
24	87.543	32.851	80.896	42.503	1976.663	120.181	666.434	159.648
25	87.849	34.694	81.663	43.860	1899.010	121.963	674.264	159.519
26	88.167	36.583	82.429	45.262	1827.382	123.675	682.309	159.373
27	88.499	38.521	83.194	46.711	1761.108	125.319	690.580	159.210
28	88.843	40.508	83.958	48.211	1699.615	126.900	699.085	159.030
29	89.202	42.546	84.721	49.762	1642.407	128.419	707.835	158.831
30	89.573	44.637	85.482	51.368	1589.055	129.882	716.840	158.615
31	89.958	46.781	86.242	53.030	1539.186	131.289	726.113	158.381
32	90.357	48.980	86.999	54.751	1492.472	132.643	735.665	158.128
33	90.770	51.235	87.754	56.534	1448.627	133.947	745.509	157.857
34	91.196	53.549	88.507	58.382	1407.396	135.203	755.659	157.566
35	91.636	55.923	89.257	60.298	1368.556	136.412	766.130	157.256
36	92.091	58.358	90.005	62.284	1331.906	137.577	776.935	156.927
37	92.559	60.857	90.748	64.346	1297.268	138.700	788.093	156.577
38	93.042	63.420	91.489	66.485	1264.484	139.781	799.621	156.206
39	93.539	66.051	92.225	68.707	1233.409	140.822	811.536	155.815
40	94.051	68.750	92.958	71.014	1203.916	141.825	823.859	155.403
41	94.578	71.520	93.686	73.413	1175.888	142.791	836.611	154.968
42	95.119	74.363	94.410	75.907	1149.220	143.721	849.814	154.512
43	95.675	77.281	95.129	78.502	1123.817	144.617	863.493	154.033
44	96.246	80.276	95.842	81.203	1099.592	145.479	877.674	153.531
45	96.833	83.351	96.550	84.016	1076.466	146.308	892.384	153.005
46	97.435	86.507	97.253	86.947	1054.367	147.106	907.653	152.455
47	98.053	89.748	97.949	90.004	1033.229	147.873	923.513	151.880
48	98.686	93.075	98.640	93.193	1012.991	148.611	939.999	151.279
49	99.335	96.491	99.323	96.522	993.599	149.320	957.148	150.653
50	100.000	100.000	100.000	100.000	975.000	150.000	975.000	150.000

Table 17. Crossing over value (COV) and their standard errors based on the product method when one character pair is determined by two inhibiting factor differences and the other character pair by three complementary factor differences–3 : 13 and 27 : 37 for F_2 or 1 : 3 and 1 : 7 for backcross (BC)

COV %	Ratio of products, %				$\sqrt{n}$ × (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	78.674	1.261	50.546	27.942	26989.01	39.830	277.479	256.948
2	78.697	2.543	51.492	28.627	13494.82	56.090	280.524	256.970
3	78.736	3.847	52.445	29.329	8996.911	68.406	283.618	256.971
4	78.790	5.174	53.404	30.049	6748.059	78.655	286.761	256.950
5	78.859	6.524	54.369	30.786	5398.834	87.568	289.955	256.907
6	78.944	7.897	55.341	31.541	4499.421	95.522	293.204	256.842
7	79.044	9.293	56.317	32.316	3857.043	102.741	296.508	256.755
8	79.159	10.714	57.300	33.110	3375.313	109.373	299.871	256.646
9	79.291	12.160	58.287	33.925	3000.680	115.520	303.294	256.515
10	79.438	13.630	59.280	34.760	2701.015	121.258	306.780	256.361
11	79.601	15.126	60.278	35.618	2455.871	126.643	310.332	256.186
12	79.779	16.648	61.281	36.497	2251.619	131.720	313.951	255.987
13	79.974	18.197	62.288	37.400	2078.820	136.524	317.642	255.766
14	80.184	19.773	63.299	38.327	1930.735	141.085	321.406	255.523
15	80.411	21.376	64.314	39.279	1802.421	145.426	325.247	255.256
16	80.653	23.007	65.333	40.257	1690.170	149.567	329.168	254.966
17	80.913	24.667	66.356	41.261	1591.146	153.526	333.172	254.652
18	81.188	26.356	67.382	42.293	1503.146	157.317	337.263	254.315
19	81.481	28.075	68.411	43.354	1424.428	160.952	341.444	253.955
20	81.790	29.825	69.442	44.444	1353.599	164.444	345.719	253.570
21	82.115	31.605	70.476	45.566	1289.532	167.801	350.091	253.161
22	82.458	33.417	71.513	46.720	1231.305	171.033	354.566	252.727
23	82.819	35.261	72.551	47.907	1178.155	174.147	359.147	252.269
24	83.196	37.137	73.590	49.129	1129.447	177.150	363.839	251.786
25	83.592	39.048	74.631	50.388	1084.648	180.048	368.646	251.277
26	84.005	40.992	75.673	51.684	1043.306	182.847	373.575	250.743
27	84.436	42.971	76.715	53.019	1005.037	185.551	378.630	250.182
28	84.886	44.986	77.758	54.395	969.512	188.167	383.816	249.596
29	85.354	47.037	78.800	55.813	936.445	190.697	389.141	248.982
30	85.840	49.126	79.843	57.276	905.591	193.146	394.609	248.342
31	86.346	51.252	80.884	58.786	876.736	195.517	400.228	247.675
32	86.871	53.416	81.924	60.344	849.690	197.814	406.005	246.979
33	87.416	55.620	82.963	61.952	824.290	200.040	411.947	246.256
34	87.980	57.864	83.999	63.614	800.391	202.198	418.062	245.504
35	88.565	60.149	85.034	65.330	777.862	204.289	424.358	244.722
36	89.170	62.477	86.066	67.105	756.589	206.318	430.845	243.912
37	89.796	64.846	87.094	68.941	736.470	208.285	437.531	243.071
38	90.443	67.260	88.120	70.840	717.414	210.193	444.428	242.199
39	91.111	69.718	89.141	72.806	699.338	212.045	451.545	241.297
40	91.802	72.222	90.158	74.843	682.169	213.842	458.893	240.362
41	92.514	74.773	91.171	76.953	665.839	215.585	466.486	239.396
42	93.249	77.371	92.178	79.141	650.289	217.277	474.336	238.396
43	94.008	80.017	93.180	81.410	635.464	218.919	482.457	237.363
44	94.790	82.714	94.175	83.766	621.313	220.512	490.864	236.296
45	95.595	85.461	95.165	86.213	607.792	222.059	499.572	235.193
46	96.425	88.260	96.147	88.755	594.858	223.560	508,600	234.055
47	97.280	91.113	97.123	91.399	582.475	225.016	517.965	232.880
48	98.161	94.019	98.090	94.150	570.608	226.429	527.688	231.668
49	99.067	96.981	99.049	97.015	559.223	227.799	537.789	230.418
50	100.000	100.000	100.000	100.000	548.293	229.129	548.293	229.129

Table 18. Crossing over value (COV) and their standard errors based on the product method when one character pair is determined by two inhibiting factor differences and the other character pair by three duplicate factor differences-3 : 13 and 63 : 1 for F_2 or 1 : 3 and 7 : 1 for backcross (BC)

COV %	Ratio of products, %				$\sqrt{n}$ × (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	68.790	27.942	2.126	1.261	68610.10	256.948	113.681	39.830
2	68.818	28.627	4.254	2.543	34301.69	256.970	161.559	56.090
3	68.865	29.329	6.383	3.847	22864.05	256.971	198.863	68.406
4	68.930	30.049	8.514	5.174	17144.11	256.950	230.807	78.655
5	69.015	30.786	10.645	6.524	13711.24	256.907	259.405	87.568
6	69.118	31.541	12.776	7.897	11421.90	256.842	285.689	95.522
7	69.241	32.316	14.908	9.293	9786.018	256.755	310.273	102.741
8	69.383	33.110	17.039	10.714	8558.530	256.646	333.556	109.373
9	69.544	33.925	19.169	12.160	7603.306	256.515	355.818	115.520
10	69.725	34.760	21.298	13.630	6838.663	256.361	377.263	121.258
11	69.926	35.618	23.426	15.126	6212.622	256.186	398.047	126.643
12	70.147	36.497	25.551	16.648	5690.528	255.987	418.293	131.720
13	70.388	37.400	27.674	18.197	5248.392	255.766	438.098	136.524
14	70.650	38.327	29.793	19.773	4869.075	255.523	457.544	141.085
15	70.933	39.279	31.910	21.376	4540.010	255.256	476.700	145.426
16	71.238	40.257	34.023	23.007	4251.773	254.966	495.625	149.567
17	71.564	41.261	36.131	24.667	3997.153	254.652	515.369	153.526
18	71.912	42.293	38.234	26.356	3770.546	254.315	532.979	157.317
19	72.283	43.354	40.333	28.075	3567.524	253.955	551.494	160.952
20	72.678	44.444	42.425	29.825	3384.546	253.570	569.952	164.444
21	73.096	45.566	44.512	31.605	3218.745	253.161	588.387	167.801
22	73.538	46.720	46.592	33.417	3067.775	252.727	606.829	171.033
23	74.005	47.907	48.664	35.261	2929.698	252.269	625.310	174.147
24	74.498	49.129	50.729	37.137	2802.898	251.786	643.856	177.150
25	75.017	50.388	52.786	39.048	2686.019	251.277	662.496	180.048
26	75.563	51.684	54.834	40.992	2577.911	250.743	681.255	182.847
27	76.137	53.019	56.873	42.971	2477.597	250.182	700.160	185.551
28	76.739	54.395	58.902	44.986	2384.237	249.596	719.235	188.167
29	77.371	55.813	60.922	47.037	2297.109	248.982	738.505	190.697
30	78.034	57.276	62.930	49.126	2215.584	248.342	757.996	193.146
31	78.728	58.786	64.927	51.252	2139.117	247.675	777.733	195.517
32	79.455	60.344	66.912	53.416	2067.229	246.979	797.741	197.814
33	80.216	61.952	68.885	55.620	1999.499	246.256	818.047	200.040
34	81.012	63.614	70.845	57.864	1935.557	245.504	838.676	202.198
35	81.844	65.330	72.792	60.149	1875.074	244.722	859.657	204.289
36	82.715	67.105	74.724	62.477	1817.757	243.912	881.017	206.318
37	83.625	68.941	76.642	64.846	1763.344	243.071	902.785	208.285
38	84.576	70.840	78.545	67.260	1711.602	242.199	924.993	210.193
39	85.571	72.806	80.433	69.718	1662.321	241.297	947.672	212.045
40	86.610	74.843	82.304	72.222	1615.312	240.362	970.854	213.842
41	87.696	76.953	84.158	74.773	1570.403	239.396	994.576	215.585
42	88.831	79.141	85.995	77.371	1527.439	238.396	1018.873	217.277
43	90.017	81.410	87.814	80.017	1486.281	237.363	1043.785	218.919
44	91.258	83.766	89.615	82.714	1446.799	236.296	1069.353	220.512
45	92.555	86.213	91.397	85.461	1408.876	235.193	1095.621	222.059
46	93.911	88.755	93.159	88.260	1372.406	234.055	1122.635	223.560
47	95.331	91.399	94.901	91.113	1337.291	232.880	1150.446	225.016
48	96.816	94.150	96.622	94.019	1303.440	231.668	1179.105	226.429
49	98.371	97.015	98.322	96.981	1270.769	230.418	1208.670	227.799
50	100.000	100.000	100.000	100.000	1239.203	229.129	1239.203	229.129

Table 19. Crossing over value (COV) and their standard errors based on the product method when both character pairs are determined by three complementary factor differences-27 : 37 and 27 : 37 for F_2 or 1 : 7 and 1 : 7 for backcross (BC)

COV %	Ratio of products, %				$\sqrt{n}$ × (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	71.565	1.508	37.499	36.621	15291.95	56.416	152.463	432.014
2	71.594	3.033	38.536	37.256	7646.092	79.568	154.242	430.994
3	71.643	4.574	39.589	37.905	5097.520	97.188	156.048	429.953
4	71.710	6.132	40.655	38.568	3823.272	111.920	157.882	428.891
5	71.798	7.707	41.736	39.247	3058.752	124.793	159.746	427.808
6	71.905	9.299	42.832	38.941	2549.097	136.336	161.639	426.702
7	72.031	10.909	43.941	40.651	2185.079	146.864	163.564	425.574
8	72.177	12.536	45.064	41.378	1912.083	156.582	165.522	424.424
9	72.343	14.182	46.201	42.121	1699.769	165.634	167.513	423.251
10	72.529	15.845	47.351	42.883	1529.932	174.125	169.541	422.055
11	72.735	17.526	48.515	43.662	1390.987	182.133	171.605	420.836
12	72.961	19.226	49.691	44.461	1275.210	189.722	173.707	419.593
13	73.207	20.945	50.881	45.279	1177.256	196.940	175.850	418.325
14	73.475	22.682	52.082	46.117	1093.304	203.827	178.034	417.034
15	73.763	24.439	53.296	46.976	1020.555	210.416	180.261	415.717
16	74.072	26.215	54.522	47.857	956.906	216.736	182.533	414.375
17	74.402	28.011	55.759	48.760	900.753	222.809	184.853	413.007
18	74.754	29.826	57.007	49.687	850.845	228.656	187.221	411.614
19	75.127	31.662	58.266	50.637	806.197	234.294	189.640	410.193
20	75.523	33.518	59.535	51.613	766.019	239.739	192.112	408.746
21	75.941	35.394	60.815	52.615	729.672	245.005	194.639	407.272
22	76.381	37.292	62.104	53.643	696.633	250.102	197.224	405.770
23	76.845	39.210	63.403	54.700	666.472	255.041	199.869	404.240
24	77.333	41.150	64.710	55.786	638.828	259.832	202.577	402.681
25	77.844	43.111	66.025	56.902	613.398	264.484	205.351	401.092
26	78.379	45.094	67.349	58.050	589.927	269.004	208.192	399.474
27	78.939	47.099	68.680	59.231	568.197	273.399	211.105	397.826
28	79.524	49.127	70.018	60.446	548.022	277.676	214.093	396.147
29	80.134	51.177	71.362	61.697	529.240	281.839	217.158	394.436
30	80.771	53.251	72.712	62.984	511.712	285.896	220.305	392.693
31	81.435	55.347	74.067	64.311	495.315	289.849	223.537	390.918
32	82.125	57.467	75.427	65.678	479.945	293.705	226.859	389.110
33	82.843	59.611	76.792	67.088	465.507	297.467	230.274	387.268
34	83.590	61.778	78.160	68.542	451.919	301.139	233.786	385.391
35	84.365	63.971	79.531	70.042	439.107	304.725	237.402	383.479
36	85.170	66.188	80.904	71.591	427.008	308.227	241.125	381.531
37	86.006	68.430	82.279	73.191	415.562	311.650	244.962	379.546
38	86.872	70.697	83.655	74.843	404.718	314.996	248.917	377.523
39	87.771	72.990	85.032	76.552	394.430	318.267	252.997	375.463
40	88.701	75.309	86.408	78.320	384.655	321.467	257.208	373.363
41	89.666	77.654	87.784	80.149	375.356	324.598	261.557	371.223
42	90.664	80.026	89.157	82.043	366.499	327.662	266.053	369.043
43	91.698	82.424	90.529	84.006	358.052	330.661	270.701	366.820
44	92.767	84.850	91.897	86.040	349.987	333.597	275.512	364.554
45	93.874	87.304	93.262	88.150	342.279	336.473	280.493	362.245
46	95.019	89.786	94.622	90.341	334.905	339.290	285.655	359.891
47	96.202	92.296	95.976	92.616	327.842	342.049	291.009	357.490
48	97.426	94.835	97.325	94.981	321.071	344.753	296.565	355.042
49	98.692	97.403	98.666	97.440	314.573	347.403	302.335	352.546
50	100.000	100.000	100.000	100.000	308.333	350.000	308.333	350.000

Table 20. Crossing over value (COV) and their standard errors based on the product method when one character pair is determined by three complementary factor differences and the other character pair by three duplicate factor differences–27 : 37 and 63 : 1 for F_2 or 1 : 7 and 1 : 7 for backcross (BC)

COV %	Ratio of products, %				$\sqrt{n}\times$ (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	56.252	36.621	1.510	1.508	34997.62	432.014	75.542	56.416
2	56.292	37.256	3.042	3.033	17499.55	430.994	107.009	79.568
3	56.357	37.905	4.595	4.574	11667.18	429.953	131.289	97.188
4	56.449	38.568	6.169	6.132	8751.239	428.891	151.879	111.920
5	56.567	39.247	7.764	7.707	7001.860	427.808	170.138	124.793
6	56.711	39.941	9.381	9.299	5835.761	426.702	186.760	136.336
7	56.883	40.651	11.020	10.909	5002.959	425.574	202.160	146.864
8	57.081	41.378	12.680	12.536	4378.465	424.424	216.609	156.582
9	57.306	42.121	14.362	14.182	3892.837	423.251	230.296	165.634
10	57.559	42.883	16.066	15.845	3504.411	422.055	243.360	174.125
11	57.839	43.662	17.792	17.526	3186.673	420.836	255.906	182.133
12	58.148	44.461	19.539	19.226	2921.947	419.593	268.017	189.722
13	58.485	45.279	21.309	20.945	2697.993	418.325	279.759	196.940
14	58.851	46.117	23.100	22.682	2506.071	417.034	291.188	203.827
15	59.247	46.976	24.913	24.439	2339.769	415.717	302.350	210.416
16	59.673	47.857	26.748	26.215	2194.278	414.375	313.283	216.736
17	60.129	48.760	28.604	28.011	2065.921	413.007	324.021	222.809
18	60.616	49.687	30.483	29.826	1951.839	411.614	334.595	228.656
19	61.135	50.637	32.382	31.662	1849.771	410.193	345.031	234.294
20	61.686	51.613	34.304	33.518	1757.910	408.746	355.353	239.739
21	62.270	52.615	36.246	35.394	1674.795	407.272	365.582	245.005
22	62.889	53.643	38.209	37.292	1599.226	405.770	375.740	250.102
23	63.542	54.700	40.194	39.210	1530.216	404.240	385.844	255.041
24	64.232	55.786	42.199	41.150	1466.939	402.681	395.912	259.832
25	64.958	56.902	44.224	43.111	1408.702	401.092	405.960	264.484
26	65.722	58.050	46.269	45.094	1354.919	399.474	416.006	269.004
27	66.525	59.231	48.335	47.099	1305.090	397.826	426.063	273.399
28	67.368	60.446	50.419	49.127	1258.786	396.147	436.148	277.676
29	68.253	61.697	52.523	51.177	1215.638	394.436	446.274	281.839
30	69.181	62.984	54.645	53.251	1175.325	392.693	456.453	285.896
31	70.153	64.311	56.786	55.347	1137.567	390.918	466.712	289.849
32	71.171	65.678	58.944	57.467	1102.121	389.110	477.051	293.705
33	72.237	67.088	61.119	59.611	1068.771	387.268	487.491	297.467
34	73.352	68.542	63.311	61.778	1037.327	385.391	498.047	301.139
35	74.518	70.042	65.519	63.971	1007.621	383.479	508.732	304.725
36	75.738	71.591	67.742	66.188	979.502	381.531	519.563	308.227
37	77.014	73.191	69.980	68.430	952.838	379.546	530.556	311.650
38	78.348	74.843	72.232	70.697	927.507	377.523	541.727	314.996
39	79.742	76.552	74.497	72.990	903.403	375.463	553.094	318.267
40	81.199	78.320	76.774	75.309	880.428	373.363	564.674	321.467
41	82.722	80.149	79.062	77.654	858.494	371.223	576.486	324.598
42	84.315	82.043	81.361	80.026	837.522	369.043	588.549	327.662
43	85.980	84.006	83.669	82.424	817.439	366.820	600.885	330.661
44	87.721	86.040	85.986	84.850	798.180	364.554	613.515	333.597
45	89.542	88.150	88.310	87.304	779.684	362.245	626.462	336.473
46	91.446	90.341	90.641	89.786	761.896	359.891	639.751	339.290
47	93.440	92.616	92.976	92.296	744.765	357.490	653.407	342.049
48	95.526	94.981	95.315	94.835	728.245	355.042	667.458	344.753
49	97.711	97.440	97.657	97.403	712.293	352.546	681.935	347.403
50	100.000	100.000	100.000	100.000	696.868	350.000	696.868	350.000

Table 21. Crossing over value (COV) and their standard errors based on the product method when both character pairs are determined by three duplicate factor differences–63 : 1 and 63 : 1 for F_2 or 7 : 1 and 7 : 1 for backcross (BC)

COV %	Ratio of products, %				$\sqrt{n}\times$ (Standard error), %			
	ad/bc, Repulsion		bc/ad, Coupling		ad/bc, Repulsion		bc/ad, Coupling	
	F_2	BC	F_2	BC	F_2	BC	F_2	BC
1	0.039	1.508	23.181	36.621	1599.990	56.416	1504.159	432.014
2	0.155	3.033	23.719	37.256	1599.960	79.568	1506.031	430.994
3	0.349	4.574	24.273	37.905	1599.909	97.188	1507.886	429.953
4	0.620	6.132	24.846	38.568	1599.839	111.920	1509.723	428.891
5	0.969	7.707	25.436	39.247	1599.748	124.793	1511.544	427.808
6	1.396	9.299	26.046	39.941	1599.637	136.336	1513.348	426.702
7	1.900	10.909	26.676	40.651	1599.506	146.864	1515.134	425.574
8	2.482	12.536	27.326	41.378	1599.355	156.582	1516.903	424.424
9	3.142	14.182	27.998	42.121	1599.184	165.634	1518.655	423.251
10	3.880	15.845	28.692	42.883	1599.992	174.125	1520.390	422.055
11	4.696	17.526	29.410	43.662	1598.781	182.133	1522.107	420.836
12	5.590	19.226	30.153	44.461	1598.549	189.722	1523.807	419.593
13	6.563	20.945	30.922	45.279	1598.297	196.940	1525.490	418.325
14	7.614	22.682	31.718	46.117	1598.025	203.827	1527.154	417.034
15	8.744	24.439	32.542	46.976	1597.734	210.416	1528.802	415.717
16	9.952	26.215	33.395	47.857	1597.421	216.736	1530.432	414.375
17	11.240	28.011	33.280	48.760	1597.089	222.809	1532.044	413.007
18	12.606	29.826	35.198	49.687	1596.737	228.656	1533.638	411.614
19	14.053	31.662	36.150	50.637	1596.365	234.294	1535.214	410.193
20	15.578	33.518	37.137	51.613	1595.973	239.739	1536.773	408.746
21	17.184	35.394	38.163	52.615	1595.561	245.005	1538.314	407.272
22	18.870	37.292	39.228	53.643	1595.129	250.102	1539.837	405.770
23	20.636	39.210	40.336	54.700	1594.676	255.041	1541.342	404.240
24	22.483	41.150	41.487	55.786	1594.204	259.832	1542.828	402.681
25	24.411	43.111	42.685	56.902	1593.712	264.484	1544.297	401.092
26	26.420	45.094	43.932	58.050	1593.200	269.004	1545.748	399.474
27	28.510	47.099	45.230	59.231	1592.669	273.399	1547.180	397.826
28	30.682	49.127	46.583	60.446	1592.117	277.676	1548.594	396.147
29	32.937	51.177	47.994	61.697	1591.545	281.839	1549.990	394.436
30	35.274	53.251	49.465	62.984	1590.954	285.896	1551.368	392.693
31	37.694	55.347	51.002	64.311	1590.343	289.849	1552.727	390.918
32	40.197	57.467	52.606	65.678	1589.712	293.705	1554.068	389.110
33	42.784	59.611	54.283	67.088	1589.061	297.467	1555.390	387.268
34	45.455	61.778	56.037	68.542	1588.390	301.139	1556.694	385.391
35	48.210	63.971	57.872	70.042	1587.700	304.725	1557.979	383.479
36	51.050	66.188	59.795	71.591	1586.990	308.227	1559.245	381.531
37	53.976	68.430	61.810	73.191	1586.260	311.650	1560.493	379.546
38	56.987	70.697	63.923	74.843	1585.511	314.996	1561.723	377.523
39	60.085	72.990	66.140	76.552	1584.742	318.267	1562.933	375.463
40	63.269	75.309	68.470	78.320	1583.954	321.467	1564.125	373.363
41	66.541	77.654	70.920	80.149	1583.146	324.598	1565.298	371.223
42	69.900	80.026	73.497	82.043	1582.319	327.662	1566.452	369.043
43	73.348	82.424	76.211	84.006	1581.472	330.661	1567.587	366.820
44	76.884	84.850	79.072	86.040	1580.605	333.597	1568.703	364.554
45	80.510	87.304	82.090	88.150	1579.719	336.473	1569.800	362.245
46	84.226	89.786	85.278	90.341	1578.814	339.290	1570.878	359.891
47	88.032	92.296	88.648	92.616	1577.890	342.049	1571.938	357.490
48	91.929	94.835	92.214	94.981	1576.946	344.753	1572.977	355.042
49	95.918	97.403	95.993	97.440	1575.982	347.403	1573.998	352.546
50	100.000	100.000	100.000	100.000	1575.000	350.000	1575.000	350.000

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Studies on transit and storage methods of lychees[1]

Shue-cheng Lin and Hui-ling Chiang[2]

Abstract Maturity standards, storage temperatures, packaging methods and some chemicals for prolonging the storage life of lychee were studied. Lychee harvested at 7 "fen" or about 70% coloring had an acceptable color and flavor and a storage life of 47 days at 5°C. Similar fruit harvested when fully ripe had a storage life of only 19 days and that harvested at green-mature stage had a storage life of 29 days.

Unwrapped lychee turned into brown completely in 4 days at 20°C and in 8 days at 5°C or 0°C. Lychee packed in polyethylene (PE) bags, boxes or trays extended their storage life substantially. The packed fruit only had a negligible decay in 4 weeks at 0°C. Packages of molded PE trays covered with Magi-film, which had a shinny attractive appearence, seemed promising.

Antisenescencing plant growth regulators (2, 4-D and kinetin), wetting agents (calcium chloride and sodium chloride) and waxing had no effect on prolonging the postharvest life of lychee. Systematic fungicides (Benlate and TBZ) were effective in controlling decay but not in retaining red color. CMC (carboxymethyl cellulose) plus citric acid coating was slightly effective in retarding browning but had no effect on decay control. A postharvest handling flow chart was designed for exporting lychee use.

Lychee (*Litchi chinesis* Sonn.) is a subtropical fruit esteemed as the "king of fruit" in China for thousands of years [13]. It is now widely grown in the southern and central parts of Taiwan. Each year, limited quantities of lychee are exported to southeastern Asia countries and Japan. The biggest difficulty of lychee in export trade has been that lychee has a very short harvest season and a very short postharvest life. Soon after harvest it loses the attractive red color and turns into dull brown. After the color change, lychee is very susceptible to fungal decay. Thus, to extend the postharvest life of lychee and to maintain the fruit in good quality during export transit is of great importance.

Desiccation and decay have long been regarded as two vital problems during storage of lychees. Various methods, such as refrigeration [4,8,17,18], paper or polymeric film packaging [9,11,12], irradiation [2,3,16], and chemical treatment [5,11] have been tested to control decay and to extend the storage life.

Postharvest diseases caused by *Aspergillus*, *Cylindrocarpon*, *Botryodiplodia*, and *Colletotrichum* have been reported [20]. A species of *Peronophythora* has also been found to

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be parasitic on lychees in Taiwan [6]. Decay organisms which caused fermentation and decay of stored lychees have been isolated and turned out to be bacteria, yeast, and other fungi in the proportion of 3 : 96 : 1, respectively [22].

Lychees grown in central Taiwan usually attain their green mature stage in early June. After this stage, they still increase their size and weight accompanying color changes. Fruits turn their green color to red about in 3 weeks. During this period, the acid content changes significantly but total sugar content changes little [10] and the fructose content rises progressively [21]. Lychee at it's "50-70%" coloring has claimed to possess the best quality for canning [10].

This study was to determine the optimum harvesting maturity and storage temperature, usefulness of various packaging methods, and the effectiveness of several chemicals on the prevention of peel browning of lychees. The objective was to develope a practical postharvest handling method which could be applied in lychee transit and storage.

Materials and Methods

This study was conducted in 1980. The fruit used in the experiment was grown in Nantou, Taiwan. and harvested from 10-year-old trees of 'Hak Ip' cultivar. Immediately after harvest by clipping, bunches of the stems of the fruit, were placed in cartons with non-perforate polyethylene (PE) liner and trucked directly to the laboratory. Then the pedicles were clipped and lychees were seperated into individual fruits and sorted into different classes according to the size and color. The mechanically-damaged and off-typed fruits were discarded. Since fruits of the same cluster (inflorescence) did not mature evenly, only those of proper maturity were selected for this experiment. Each class of fruits after sorting was evenly distributed into the test lots to minimize the diversity of the samples.

Lychees harvested on June 10, 15, 20, 25, and 30 corresponded to local farmer's maturity standard of 6, 7, 8, 9, and 10 "fen", respectively. The color of the outside layer of the peel and the inner membrane of the peel were determined with a color and color differential meter (Nippon Denshoku model ND-1010 CD) by using pink and yellow standards [19]. The value of "L" indicated the lightness of color (100=white and 0= black); "a" indicated red when the value was positive, gray when zero and green when negative ; "b" indicated yellow when the value was positive, gray when zero and blue when negative.

After the color test, fruit juice was extracted for acidity and soluble solids analysis. The total acidity was determined by titrating an aliquot of flesh extracts with standardized sodium hydroxide using phenolphthalin indicator. Total soluble solids was measured with hand refractometer (Bausch & Lomb model 32).

Fruits harvested on June 20 and 4 replications with 15-50 fruits per sample in each treatment were used for stored temperature, packaging, and chemical dipping studies. The color and flavor of the fruit before and after test were evaluated. Numerical scales were used to express the degree of browning : 1=all red, 2=browning on tips of tubercles only, 3=brown spots up to 0.5 cm in diameter, 4=large brown sports over 0.5 cm in

diameter, and 5=all brown. The flavor of the fruit was rated as excellent, good, fair, poor and inedible by a panel test with 7 panelists. All fruits before test were rated as grade 1 in color and excellent in flavor.

Chemicals with fungicidal, antisenescence or wetting properties were screened for their effectiveness in preventing browning and decay and purchased from various companies : kinetin from Sigma Chemical Co., USA ; 2, 4-D (2, 4-dichloroacetic acid) from Tokyo Kasei Chemical Co., Japan ; calcium chloride and sodium chloride from Merck Inc., West German ; TBZ (thiabendazole, 2-(4-thiazolyl) benzimidazole, Mertect) from Merck, Sharp & Dohme International, USA ; Benlate (methyl-(1 butyl carbamoyl)-2-benzimidazole carbamic acid) from Du Pont Co., USA ; CMC (carboxymethyl cellulose) from Nichlin Chemical Co. Japan and Tag® as a generous gift from M. C. W. Co., Israel. Fruits were dipped in aqueous solution at concentrations indicated in Table 6 for four minutes.

Various packaging materials were also tested for their effectiveness in extending storage life. Magi-film®(0.012 m/m thick) made of ethylene vinyl acetate copolymer resin with special antifog treatment is a product of Chiyi Industrial Co., Taiwan. Molded PE meal box (11×7.5×2.5 cm, 0.17 m/m thick) was purchased from local supermarket ; PE tray has the same size as the meal box but without flat cover, was also purchased from local market.

Samples either packed or not were placed in ventilated PE bins (4×30×10cm) which were kept in storage rooms maintained at assigned temperatures and 85-90% relative humidity. Temperature of each storage room was thermostatically controlled with ±0.5°C accuracy.

Results

Maturity test

A maturity description based on color changes of tubercles, the ground of the peel and the inner membrane of the peel was made to code to the presently used but not yet well defined numerical maturity standard "fen" (Table 1). The description covers a range from 5 "fen", at which the fruit was green-mature, to 10 "fen" when the fruit was over ripen.

Table 1. Description of color changes coded to maturity standard of 'Hak Ip' lychee by "fen" unit

Maturity[a]	Color changes in different parts of the peel		
"fen"	Ground	Tubercles	Inner membrance
5	green	green	white
6	yellow first appeared	red on the tip of yellow ground	white
7	1/3 red	1/2 red	white tinted with light red
8	1/3 to all light	1/3 brown on tip	1/2 red
9	red	all brown on tip	red
10	dully red	brown	deep red

a. Maturity expressed with "fen" unit is presently used by Taiwan farmers ; 6 "fen" is about turning stage.

Values of color components, either in outer or inner membrane of the peel changed drastically during fruit ripening (Figure 1). The brightness "L" of the outer peel decreased as the fruit ripened and a sharp decrease occured between 8 and 9 "fen". Red color "a" increased drastically from 6 to 8 "fen", then decreased sharply. Like brightness, the value of yellow "b" decreased as ripening progressed and had a rapid change between 6 and 8 "fen". Changes of color components in inner membrane of the peel followed nearly the same pattern as those of outer peel. The slight differences noticed are that the brightness of inner membrane changed little during ripening ; red color "a" increased as ripening progressed and the most drastic change was observed with one stage delay starting from 7 to 9 "fen".

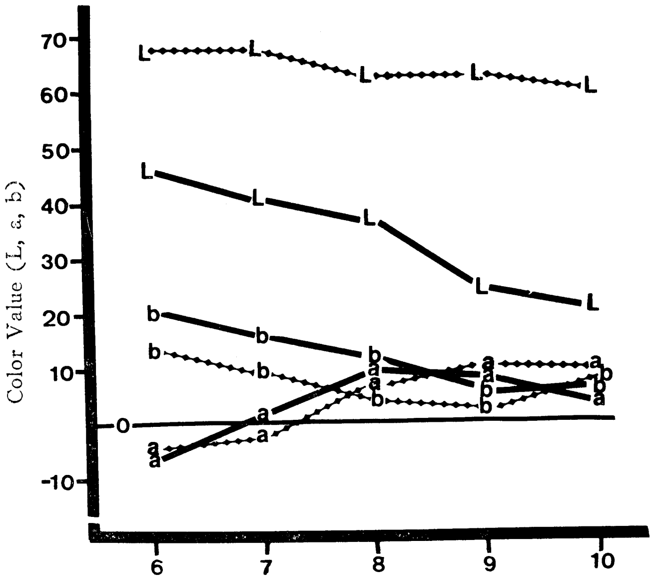

Fig. 1. Changes of color values of outer peel (solid line) and inner membrane (dotted line) at different stages of maturation of lychee. "L" values are : from 100 (white) to 0 (black) ; "a" values are : red (+), gray (0), green (−) ; "b" values are : yellow (+), gray (0), blue (−).

A progressive decrease in acid content and increase in total soluble solid was found during fruit ripening (Table 2). Significant acidity and soluble solid content occured between 6 and 7 "fen" which corresponded to a flavor change from poor to good. Although the flavor at 8 and 9 "fen" was rated as excellent, the storage life of lychee harvested at these stages were very short. The fruit harvest at 7 "fen" had the longest storage life.

Storage temperature vs. browning

The result of storing unpackaged fruit at 0°, 5°, 10°, 15° and 20°C was summarized in Table 4. Under high relative humidity (85-90%) conditions, lychee could retain its freshness and good color for only 2 days at 20°C ; and it attained complete browning in 4 days at this high temperature. The fruit stored at≦5°C did not turn to brown completely before 8 days, however. The fruit had no decay or off-flavor developed but the rind

became brittle and very easy to crack as a result of dessication.

Table 2. The quality and storage life of lychee harvested at different stages of matuation

Maturity ("fen")	Acid content as malic acid (%) (x10^{-2})	Total soluble content (Brix)	Flavor	Storage life[a] (days)
6	0.29±3.1	14.0±2.9[b]	poor	29±6
7	0.21±2.6	17.0±1.7	good	47±4
8	0.17±0.8	17.3±2.1	excellent	30±3
9	0.16±1.3	18.1±2.4	excellent	25±4
10	0.13±20	18.0±2.6	good	19±3

a. Storage condition : 0°C, 85-90% R. H. ; storage life was ended when the fruit became inedible.
b. Standard deviation.

Table 3. Temperature effect on the browning rate of lychees stored at 85-90% R. H.

Temperature (0°C)	Cumulative percent of browing			
	2 days	4 days	6 days	8 days
0	0	68	87	100
5	0	75	90	100
10	0	81	100	
15	0	93	100	
20	0	100		

Table 4. Effect of various packaging methods on the prevention of browning of lychee at 0°C, 85-90% R. H.

Packaging	Scores of browning[a]			
	1 week	2 weeks	3 weeks	4 weeks
PE bag (unsealed)	4.86 a[c]	5.00 a	5.00 a	5.00 a
PE bag (sealed)	2.13 cd	2.54 f	3.18 cd	3.81 cd
PE bag (sealed)+paper liner	2.00 cdef	2.24 g	3.09 cde	3.42 cde
PE molded meal box (stapled)	3.53 b	4.20 b	5.00 a	5.00 a
PE molded meal box+moistened pulp[b]	2.11 c	2.88 d	3.24 c	3.85 c
PE molded meal box+moistened sawdust[b]	2.29 c	3.17 c	3.53 b	4.14 b
PE molded meal box+moistened paper liner[b]	1.90 def	2.69 e	3.00 cde	3.57 cde
PE molded tray covered with Magi-film®	1.78 f	2.30 g	2.39 e	3.16 e
Waxing (Tag®)	4.80 a	5.00 a	5.00 a	5.00 a
CK (unwrapped)	5.00 a	5.00 a	5.00 a	5.00 a

a. Rating scale : 1=all red, 2=brown on tips of tubercles, 3=brown spots up to 0.5 cm diameter, 4=large brown spots, 5=all brown.
b. Scotch tape sealed with a pinhole at each end.
c. Means with same letter within a column are not significantly different at 1% level.

Effect of packaging on browning

Browning was delayed by packaging lychee in PE bag, molded PE boxes or trays (Table 4) . Packaged fruit retained its color at least 2 to 4 times longer than unpackaged fruit. Waxing the fruit or keeping the fruit in unsealed PE bags had little effect on preventing fruit browning. The fruit kept in PE bags and in molded meal boxes turned brown more slowly than the unwrapped one. The fruit in PE tray covered with Magi-film turned brown most slowly. Moistened pulp and moistened paper liner had a better ability to maintain moisture in the package than moistend sawdust.

Chemicals vs. browning and decay

Systematic fungicides, TBZ and Benlate, had a good effect in decay control but had no effect in delaying browning (Table 5). Antisenscence plant growth regulators, 2, 4-D and kinetin, had no effect either in retarding peel browning or decay control. Wetting agents, 4% calcium chloride or 5% sodium chloride damaged the fruit osmotically and, hence, accelerated browning. CMC coating was slight effective in preventing browning when lychee stored for 12 days but not effective in controlling decay.

Table 5. Effect of chemicals on the control of decay and browning of lychee in perforated PE bag stored at 10°C, 85-90% R. H.

Chemicals	scores of browning and percent of decay			
	3 days	6 days	12 days	12 days
	Browning[a]	Browning	Browning	Decay (%)
TBZ 1000 ppm	2.60 bc[b]	3.40 bc	5.00 a	0.00 c
Benlate 1000 ppm	2.45 bcd	3.20 cd	5.00 a	0.00 c
Benlate 1000 ppm+2% $CaCl_2$	2.50 bcd	3.20 cd	4.80 ab	0.00 c
4% $CaCl_2$	4.10 a	5.00 a	5.00 a	13.50 ab
5% $NaCl_2$	4.50 a	5.00 a	5.00 a	16.50 a
1% CMC+0.05% citric acid	2.05 d	2.85 d	4.50 b	11.00 b
2, 4-D 50ppm	2.75 b	3.75 b	5.00 a	14.50 ab
kinetin 25ppm	2.35 bcd	3.25 cd	5.00 a	14.00 ab
CK_1 (untreated)	2.50 bcd	3.75 b	5.00 a	14.50
CK_2 (water)	2.75 b	3.30 cd	5.00 a	13.50 ab

a. Brown rating scale : 1=all red, 2=brown on tips of tubercles, 3=brown spots up to 0.5 cm diameter, 4=large brown spots, 5=all brown.

b. Means with same letter within a column are not significantly different at 1% level.

Discussion and Conclusion

This experiment confirmed previous reports [24,25,26] on that while the flesh quality of lychee could be maintained for several weeks by proper refrigeration and packaging. External discoloration was difficult to prevent. The fruit harvested at 7-8 "fen", shortly before full ripe, had two to three times longer storage life than that harvest at fully ripe.

The fruit may be harvested even earlier if requires a long distance, but at some sacrifice of quality for exchange of durability. This study revealed that using color development of inner membrane of the peel was more dependable and easier than using ground color of the peel or the color of tubercles [10] in judging maturity since little change of brightness and red color component increased during fruit ripening was found in the inner membrane of peel.

Keeping lychee under low but unfrozen temperature is essential in delaying fruit browning [9,18]. This study confirmed that quick browning would occur when the storage temperature was higher than 10°C, Therefore a prompt precooling to remove field heat of the fruit should be a good practice. Few information on chilling injury of lychee is available yet. However, there was some indication that lychee might suffer some extent of chilling injury during a period of cold storage since the fruit after storage turned to brown quickly at room temperature. The symptom of browning developed after cold storage was the same as that caused by desiccation.

Desiccation, which causes fruit browning, should be avoided during handling, storage and transit of lychee [15]. Anatomical studies (data not shown) revealed that natural wax covering epidemical cells of lychee was thin and discontinuous. Very few or no wax found around the tip of tubercle. The thin-layered epidemal cells on the tip of tubercle were easy to break during fruit ripening and, therefore, the parenchyma cells would then be exposed to the air. This might be the reason why full ripe fruit was more prone to desiccate than partially ripen.

Waxing was not effective in preventing browning in test confirmed previous works [1,14] but was contray to the other [11]. The tips of tubercles could not easily be covered by wax during the waxing process may be the reason. Fruit treated with CMC plus citric acid slightly delayed browning. The explaination is that CMC hydrated within the break of tubercles, preventing the desiccation and oxidation [7].

Prevention of browning by packaging lychee in various PE material seemed to be due to the effect of maintaining high humidity and low oxygen atmosphere in the package. Magi-film® is considered to be a good consumer packaging material because it has a shinny appearance, adequate permeable to air and an ability to prevent condensation of water vapor on the film.

Browning was not a result of peel senescence because neither 2, 4-D or kinetin could alleviate it. Systematic fungicides TBZ and Benlate, was very effective in controlling decay and somewhat effective in preventing browning. The effect of preventing browning might to their fungicidal effect instead of growth regulatory effect [23].

The above findings suggested that prevention of desiccation is of prime importance in order to prevent browning of lychee. However, a practical device to prevent desiccation should not create an anaerobic condition of the fruit. Consumer-pack made of PE bags, molded PE boxes, and molded PE trays covered with Magi-film are useful for lychees. Although coating with CMC and citric acid was slightly preventing browning in the test, it is not worth to be recommend in practical use since effect of packaging is far better than chemical treatment in preventing browning.

Lychee for export should be harvested at 7-8 "fen" or about 70% ripe (coloring) and

should be held at a temperature below 5°C during handling, shipping and marketing. If the importer's quarantine requirement includes disinfestation of Oriental fruit fly, fumigation treatment is necessary. A portharvest handling flow chart shown as Fig. 2 is designed for exporting lychees.

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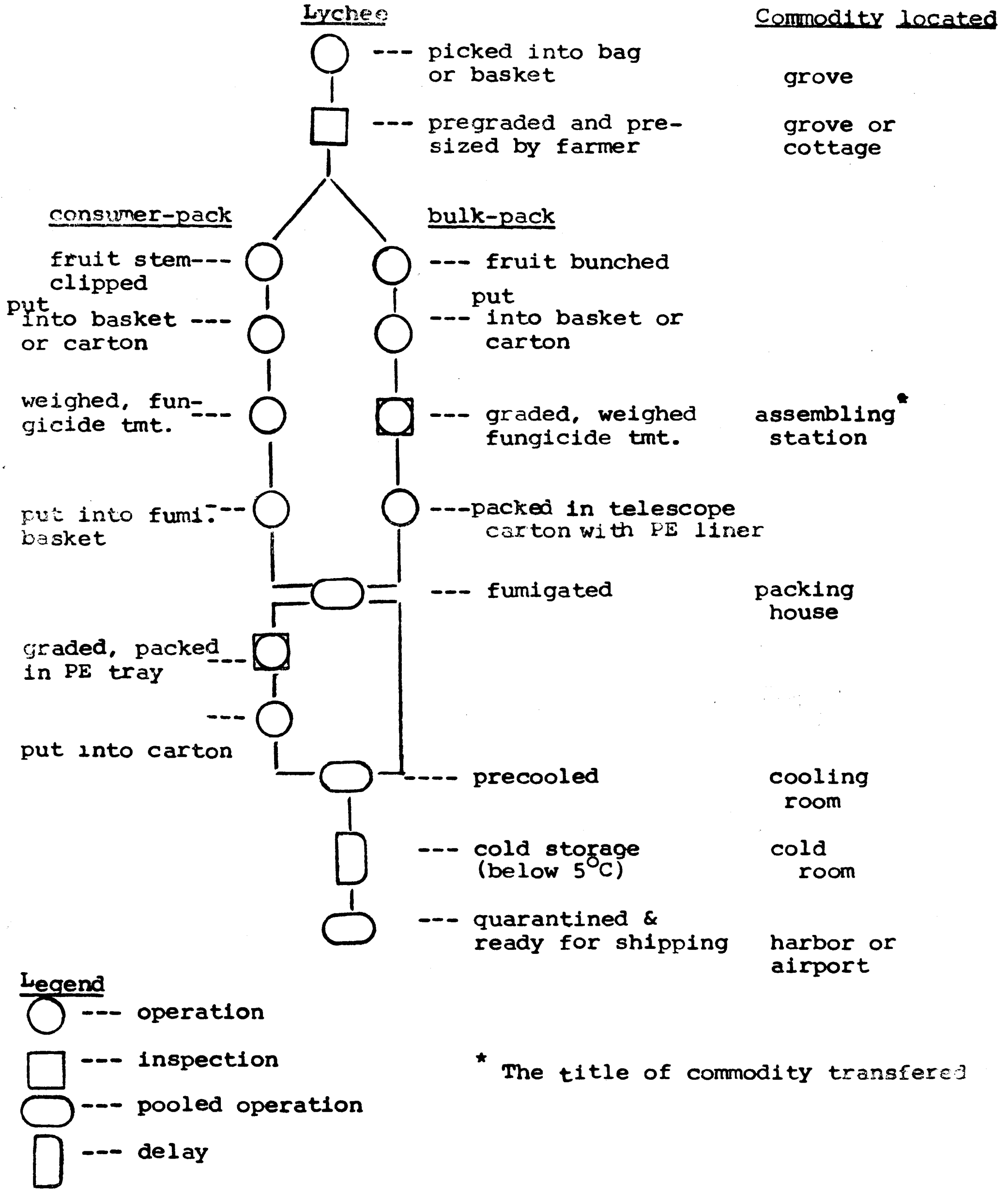

Fig. 2. Proposed Poteharvese handling flow chart for exporting lychees.

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荔枝果實貯運方法之研究[1]

林學正　江慧鈴[2]

摘　要

荔枝於採收後極易變色失味，貯運能力深受限制，本實驗就果實成熟度、包裝方法、貯運溫度與保鮮藥劑加以研究，期能尋求一適合內外銷之處理貯運方法，提供業者參考。

黑葉荔枝在七分熟時最耐貯運，在 0°C 時可貯存達 47 天之久，過熟（十分）及綠熟（五分）皆不耐貯運，各爲 19及 27 天。以兩端各留一針孔之密封 PE 盒或 PE 盤覆以 EVA 膜，皆可顯著延長貯運壽命，在 0°C 貯藏達四星期而不失色變味，尤以後者因透明不霧化，清潔美觀，適合用於小包裝。果實塗臘、浸漬抗老化植物生長素 2.4-D (50 ppm) 或 Kinetin (25 ppm) 及濕潤劑一食鹽水（5 %）或氯化鈣水（4 %），對果實變色或腐爛皆無抑制作用。食品黏糊劑 CMC (1%) 加枸櫞酸（0.05 %）水溶液處理果實，對防止果實變色稍具效果但無防止腐爛之效果。殺菌劑一霉敵或萬力 (1,000 ppm)，能有效防止果實腐爛兼稍具防止果實褐變之功效。果實在 20°C 下貯存四天即完全褐化，在 5°C 以貯存可延至第八天始完全褐化，故果實採收燻蒸後，應迅速預冷於 5°C 下貯運。應用上述試驗結果，設計一荔枝採收後之處理流程圖建議在外銷作業上使用。

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1. 臺灣省農業試驗所　研究報告　第 993 號。

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中華農業研究 (Jour. agric. Res. China) 30(3)：261～269 (1981)

澎湖縣土壤肥力與高粱磷鉀效應之關係[1]

林 家 棻[2]

摘要：澎湖縣土壤之母質主要爲玄武岩，經選取三種土壤包括冲崩積土， 殘積土及上層冲崩積土下層殘積土， 在24處舉行高粱磷鉀效應田間試驗 ， 從供試土壤性質顯示殘積土之土層厚度多在 90cm 上下，其他兩種土壤則變化較大，從 30cm 至 90cm 不等 。 pH 均在 7.7 至 8.1 間，表土含砂量多在 70 %以上，有機物含量高者僅 1.5 %，低者不及 0.5 %， 但土壤陽離子交換能量高者可達 30me/100gm，低者不及 3me/100gm ，兩者相差達10倍。土壤中 Bray P_1 含量甚低，鮮有超出 1 ppm P ，但交換性鉀則頗高，多在 100ppm K 以上，一般言之，冲崩積土肥力較高，殘積土較低，上層冲崩積土下層殘積土居中， 各種土壤上所得高粱平均收量之高低，亦有此傾向。

土壤中 Bray P_1 或 Olsen P 各與高粱磷肥效應有關，但其相關係數僅在 0.5 上下，而土壤中交換性鉀，Mehlich K 及 Olsen K 則與高粱鉀肥效應無關。經利用程式計算機，將土壤其他特性因子，參予磷鉀校正公式中，求出最適合之複相關模式爲：

$$\hat{Y}_1=2.535a-0.1393a^2-79.18c+42.58c^2+5.819ac-43.96b+430.9 \quad (1)$$

$$\hat{Y}_2=1.284a+0.124a^2+0.406d+0.0002d^2+0.034ad-97.15b+828.6 \quad (2)$$

式中 Y_1 及 Y_2 各指估計無磷區 ($P_0/P\times100$) 及無鉀區 ($K_0/K\times100$) 之高粱收量百分率，a=clay%, b=pH, c=Bray P_1 ppm, d=交換性 K ppm ，方程式（1）及（2）兩式所得複相關係數各爲0.7735及0.8362，均達1%顯著平準，確有改進功效， 文中並檢討在一定範圍內，土壤 pH ，粘土含量以及土壤有效態磷鉀含量與無磷區或無鉀區高粱收量百分率估計値之關係。

澎湖爲本省最小之一縣，面積約 126 方公里、處於臺灣海峽中央，全縣島嶼 64，其中以馬公本島最大，其次爲西嶼，再次爲白沙，島上無山，風害甚烈，年雨量僅 998.6mm， 多分布於夏秋之間，而年蒸發量則達 1,820.5mm ，梁氏 (1) 認爲由於四周環海，周年高溫濕熱，成土作用仍趨向磚紅土化 (Laterization) ，土色多呈紅，棕紅，黃棕等色， 又因蒸發量大於雨量及終年季風吹襲的影響，土壤受淋洗的作用較輕，表層微細土壤多被吹刷，使土壤呈殘缺狀，剖面層次不分明，一般高地爲殘積紅土，心土粘重，較低地爲冲崩積土，土壤剖面呈暗色，石礫質壤土，表土皆含多量珊瑚砂之砂質壤土，此等砂多爲數百年來農民以海邊珊瑚砂作爲肥料所彙集者，該縣土壤母質主爲鹽基性之玄武岩，再加海風吹襲携帶鹽分，更增加土壤鹽基性，因此 pH 多在 7.5 以上。

農作物以旱作甘藷，落花生與高粱爲主，由於水源關係，無大規模灌漑設施，農業環境欠佳，農作物之肥料試驗至感缺乏，作者將過去在該縣舉行之高粱對於磷鉀效應試驗資料，予以整理，藉以拋磚引玉，提供關心澎湖縣農業者之參考。

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1. 臺灣省農業試驗所研究報告 第 994 號。

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試驗方法

本試驗係在澎湖縣之白沙、西嶼、馬公及湖西4鄉鎮計24地點擧行田間試驗，供試土壤有冲崩積土，殘積土及上層冲崩積土下層殘積土等三種。

試驗設計：設5處理，氮用量概爲 120kg/ha，磷 (P_2O_5) 及鉀 (K_2O) 各爲0，40 及80kg/ha，三平準，其組合如下：(1) $N_{120}P_0K_{80}$, (2) $N_{120}P_{40}K_{80}$, (3) $N_{120}P_{80}K_{80}$, (4) $N_{120}P_{80}K_{40}$, (5) $N_{120}P_{80}K_0$ 重複4次，採用完全逢機區組排列，小區面積爲 $4\times5=20m^2$，磷肥以一次基肥施用，氮鉀肥分爲基肥及二次追肥施用。每次施用量各爲全量之⅓，基肥在播種前施用，第一次追肥在播種後35天施用，第二次則在50天後施用，高粱品種用金門白掃，收穫時取其種實，乾後，記載其收量，其他概照當地慣行法實施。

土樣分析：播種前各地採回之土壤經風乾、磨細、通過 2mm 篩孔後作下列分析[4]：

一、pH ：用玻璃電極法，土：水爲1：1。

二、機械分析：用浮秤法。

三、有機物：用硫酸及重鉻酸鉀氧化後，以低價鐵滴定之。

四、陽離子交換能量：用醋酸鈉法。

五、有效態磷

(一) Bray 氏法：以 0.025N HCl-0.03N NH_4F 液抽出後，比色測定之。

(二) Olsen 氏法：以 0.5M $NaHCO_3$, pH 8.5 液抽出後，比色測定之。

六、有效態鉀

(一) Mehlich 氏法：以 0.05N HCl-0.025N H_2SO_4 液抽出後，以焰光計測定之。

(二) 交換性鉀：以 1N NH_4OAc, pH 7.0 液抽出後，用焰光計測定之。

(三) Olsen 氏鉀：以 Olsen 氏法測定有效態磷之餘液，用焰光計測定之。

統計分析：將各試驗地高粱種實乾重，按照試驗設計，分別求其變方分析，測定處理及區集 (Block) 間之顯著性F值，藉以瞭解處理及地力之差異，次以施磷區或施鉀區之收量作爲 100，求無磷區或無鉀區之收量百分率各與土壤中有效態磷或有效態鉀之簡單相關，最後利用程式計算機，參予土壤其他特性因子於磷鉀速測校正公式中，求出最適合之複相關模式[5,6]：

$$\hat{Y}=a_0+a_1X+a_2X^2\times a_3Z+a_4Z^2+a_5ZX+a_6W$$

式中，$\hat{Y}$ = 估計之收量百分率，a_0-a_6 爲常數，X 爲有效態磷或有效態鉀，W 及 Z 爲供試土壤其他特性之測定值。

結果與討論

供試土壤之肥力情形：

表1.示殘積土之土層厚度變化較小，多在 80～90cm 間，其他兩種土壤則變化較大，從30乃至 90cm 以上，土壤 pH 都在 7.7—8.1 間，表土多屬砂質壤土，含砂量多在 70 %以上，有機物含量高者約 1.5 %，低者不及 0.5 %，但陽離子交換能量高低相差甚大，高者超過 30 me/100gm，低者不及 3 me/100gm，相差達10倍以上，有效態磷用 Bray 第一法測定者，鮮有超出 1 ppm P，但用 Olsen 氏測定者則不甚低，高者可達 15 ppm P，梁氏[1]用 Peech 氏法 (NaOAc, pH 4.8) 測定者則在 14～90 ppm P 間，可見土壤中潛存之磷酸含量仍然不低，土壤中交換性鉀含量頗高，多在 120～200 ppm K 間，若以有機物與陽離子交換能量來判別土壤肥力狀況而言，則以冲崩積土居高，殘積土較低，上層冲崩積土下層殘積土居中。

高粱種實收量之比較

據高雄區農業改良場澎湖工作站[2]對於高粱三要素肥料試驗結果認爲高粱生育期中若有灌溉，

表 1. 供試土壤肥力狀況

Table 1. Fertility status of soils

Soil No. *a*	Depth cm	pH	Texture	Mechanical Analysis Sand %	Silt %	Clay %	O. M. %	CEC me/100g	Available P/K ppm Bray P	Olsen P	Mehlich K	Exch. K	Olsen K
冲崩積土 Wind eroded soils													
1(21)	>85	8.1	SL	70.6	15.8	13.5	1.51	14.4	0	7.0	84.0	218.4	590
2(22)	80	8.1	SCL	65.6	7.8	26.5	0.95	17.7	0.34	14.8	68.7	210.6	485
3(25)	70	8.0	SL	72.6	16.8	10.5	1.03	11.1	0.26	14.5	52.4	140.4	425
4(51)	45	7.9	SL	73.6	11.8	12.5	0.99	14.4	0.42	14.6	48.8	144.3	380
5(52)	>80	7.9	SL	74.6	14.8	10.5	0.96	15.5	0.42	14.3	65.1	195.0	460
6(42)	30	8.0	SL	75.6	16.8	7.5	0.60	24.9	0	6.0	62.4	241.8	500
7(11)	>90	7.9	L	46.6	38.8	14.5	1.51	33.2	0.34	9.7	164.0	538.2	900
8(46)	>90	7.8	SL	71.6	17.8	10.5	0.89	14.6	0	7.2	86.3	97.5	240
9(41)	>90	7.9	SL	72.6	18.8	8.5	1.01	14.2	0.16	9.4	35.2	109.2	335
10(44)	45	7.9	SL	64.6	22.8	12.5	0.85	27.8	0	7.9	64.7	226.2	505
11(32)	65	7.9	SL	74.6	14.8	10.5	0.82	14.0	0.21	9.4	54.1	140.4	370
Mean		8.0		69.3	17.9	12.5	1.01	18.4	0.20	10.4	71.4	205.6	471
殘積土 Residual soils													
12(16)	>90	8.0	LS	80.6	8.8	10.5	1.08	11.5	0.10	10.1	57.1	148.2	395
13(20)	>90	8.0	SL	72.6	12.8	14.5	1.51	14.7	0	5.2	52.4	144.3	385
14(53)	>80	8.1	SL	71.6	17.8	10.5	0.85	22.3	0	5.6	71.4	218.4	540
15(34)	>90	8.0	SL	72.6	18.8	8.5	0.76	6.5	0	5.3	81.3	148.2	430
16(38)	>90	7.7	LS	79.6	12.8	7.5	0.60	3.2	1.01	13.0	70.0	66.3	280
17(37)	>90	7.9	LS	84.6	8.8	6.5	0.43	2.9	0.08	4.5	40.2	54.6	220
18(54)	85	8.1	SL	70.6	18.8	10.5	0.78	19.0	0	9.3	61.1	195.0	440
Mean		8.0		76.0	14.1	9.8	0.86	11.4	0.17	7.6	61.9	139.3	384
上層冲崩積土下層殘積土 Upper wind eroded soil with residual soil underneath													
19(36)	35	7.8	SL	57.6	29.8	12.8	1.13	9.8	0.42	11.0	62.4	113.1	340
20(50)	>90	7.8	L	44.6	34.8	20.5	1.26	16.7	0	6.5	82.7	245.7	570
21(55)	>90	8.0	SL	76.3	5.2	18.5	1.37	30.2	0	4.9	29.9	132.6	330
22(47)	53	7.0	SL	74.6	14.8	10.5	1.04	13.7	0.21	10.2	38.8	136.5	320
23(15)	>85	8.0	LS	85.6	5.8	8.5	0.63	6.3	0	5.3	41.1	85.8	250
24(29)	>90	8.1	LS	82.6	8.8	8.5	0.67	5.2	0	8.4	42.5	93.6	305
Mean		7.9		68.6	16.5	13.2	1.02	13.6	0.11	7.7	49.6	134.6	352

a. Figures in ( ) refer to field soil No.

種實收量可達 2,000~4,000 kg/ha ， 無灌漑者則僅 500 kg/ha 上下，氮（N）磷（P_2O_5）及鉀（K_2O）之施用量各以 120, 80 及 60 kg/ha 爲宜，並稱若無灌漑，又逢天旱，施肥反而減收。

表 2 示在 24 處試驗中，僅有 2 處高粱種實收量未達 1,000 kg/ha，其他多在 2,000 kg/ha 上下，高者甚至可達 4,000 kg/ha，一般言之，試驗結果尙屬正常，但經變方分析，其處理間差異達到顯著平準者僅有 4 處，而區間差異達到顯著平準者則有 8 處，因此，今後若在農業環境欠佳地區進行田間試驗，處理數目應力求簡單，而重複次數必須增加，方可獲得更爲可靠的結果，若就高粱種實平均收量而言，仍以冲崩積土居高，殘積土最低，上層冲崩積土下層殘積土居中，其趨向與土壤肥力狀況相符合。

表 2. 高粱種實收量及其顯着性 F 値測定

Table 2. Yields of sorghum　　公斤／公頃 kg/ha

Soil No.	Treatment No. 1	2	3	4	5	F-test Treat-ment	Block	Location	Farmers' Name
				Wind eroded soils					
1(21)	3050	2400	3750	3200	3150	*		白沙　小赤崁	許先傳
2(22)	2000	2000	1500	2700	1900			白沙　小赤崁	張春諒
3(25)	2850	2900	3400	3400	2800			白沙　港子	林　愼
4(51)	2350	2350	2450	2550	2900			白沙　後寮	葉慶德
5(52)	2150	2300	2500	2300	2400			白沙　溝美	吳竹城
6(42)	1850	1900	1950	2000	2300			馬公　五德	歐皆的
7(11)	2000	2550	2100	1850	2450			馬公　石泉	陳甲茂
8(46)	1500	1600	1650	1850	2050			馬公　西衛	王　月
9(41)	3100	3150	3400	3300	3400		*	馬公　西衛	高自權
10(44)	1850	2200	1750	2000	2050			馬公　安宅	蔡五文
11(32)	4000	4100	4000	4050	3750			湖西　西溪	莊　傳
Mean	2427	2495	2586	2654	2650				
				Residual soils					
12(16)	2850	2500	2500	2900	2200		**	白沙　赤崁	張　貴
13(20)	1250	1450	1450	1300	1300			白沙　瓦硐	吳連池
14(53)	1950	2150	2150	2200	2200			白沙　溝美	蕭鄭近
15(34)	700	650	750	700	750		*	西嶼　二嶼	陳彩雲
16(38)	2250	1750	1700	2000	2000		**	西嶼　池西	呂漢章
17(37)	600	700	650	600	600			西嶼　池東	顏以定
18(54)	2350	2300	2550	2350	2300			馬公　鳥崁	洪根朝
Mean	1707	1643	1679	1721	1621				

Soil No.	Treatment No.					F-test		Location	Farmers' Name
	1	2	3	4	5	Treat-ment	Block		
Upper wind erorded soil with residual soil underneath									
19(36)	1250	1300	1250	1250	1500		**	西嶼 池 東	鍾黃劉
20(50)	2550	3150	2800	3200	2750	*	**	馬公 安 宅	蔡 塔
21(55)	1450	2000	1850	1900	1550			馬公 鳥 崁	許耕力
22(47)	2400	2450	2350	2650	2400		**	馬公 重 光	陳福壽
23(15)	1200	1550	1550	1450	1350	**	*	湖西 紅 蘿	林祖混
24(29)	1650	1700	2300	2200	1450	**		湖西 南 寮	趙 錦
Mean	1750	2025	2017	2108	1833				

a. Figures in ( ) indicate field soil No., * and** refer to significant at 0.05 and 0.01, respectively. *b*. Treatment No : 1=$N_{120}P_0K_{80}$, 2=$N_{120}P_{40}K_{80}$, 3=$N_{120}P_{80}K_{80}$, 4=$N_{120}P_{80}K_{40}$, 5=$N_{120}P_{80}K_0$. Figures at the right side of the alphabet show the rate of N, P_2O_5 and K_2O added (kg/ha).

土壤中有效態磷鉀含量與高粱對於磷鉀效應之關係

高粱對於磷或鉀之效應指數乃以施磷區或施鉀區之收量作爲 100，求無磷區或無鉀區之收量百分率表示之，所謂施磷區與施鉀區乃以施磷或施鉀之 40 或 80 kg/ha 兩平準中，取其收量較高者作爲施磷或施鉀區之收量，不恆定取某一平準之施用量，求其指數後，再與土壤中有效態磷或鉀之測定值對數，分別求其相關係數，所得結果如表3，其中顯示土壤中有效態磷勿論採用 Bray P_1 法或 Olsen 氏法所得測定值均與高粱磷肥效應指數有顯著之相關，但其相關係數以 Bray P_1 法高於 Olsen 氏法所得者，至於有效態鉀所得三種測定值包括 Mehlich 氏法，Olsen 氏法及交換性鉀均與高粱鉀效應指數無關，事實上從表 2 可知土號 1 及24之高粱收量確可因施用鉀肥而提高，其相關係數不顯著者，可能由于未考慮土壤其他重要因子所致。

表 3. 土壤磷鉀有效指數與高粱磷鉀收量百分率之相關係數

Table 3. Correlation coefficients between soil PK and percentage yield of sorghum

Soil P	% Yield $P_0/P \times 100$	Soil K	% Yield $K_0/K \times 100$
Log P_1 Bray	0.5289**	log K Mehlich	0.0392
log P Olsen	0.4392*	log K Exchangeable	0.1749
		log K Olsen	0.1289

參予其他特性因子於土壤速測磷鉀校正公式中對於高粱磷鉀效應之關係

澎湖縣農業環境不佳，但作物收量主受環境因子的影響，環境因子中以氣候與土壤最爲重要，前者實非目前人力所能控制，因此探討土壤磷鉀含量與高粱對於磷鉀效應之關係時，若參予土壤其他性質，將有助於土壤磷鉀速測值之解釋，因此利用程式計算機將土壤磷或鉀速測值分別與土壤其他性質

因子組合運算，求出最適合之校正模式，次由該等模式所求得高粱種實收量百分率之理論值與實測值示於圖1及2中，其中顯示在澎湖地區若參予粘土含量及 pH 值於磷或鉀之田間校正模式中，則其複相關係數分別爲 0.7735** 及 0.8352**，均達極顯著平準，且較前節單憑磷或鉀速測值高出甚多，值得注意，又作者等 [3] 在本省中部測定田間水稻磷吸取量與土壤磷速測值之關係時，參予土壤其他性質因子亦爲土壤 pH 及 Clay 含量，此兩者對於土壤磷鉀供應之關係，有待進一步之研究。

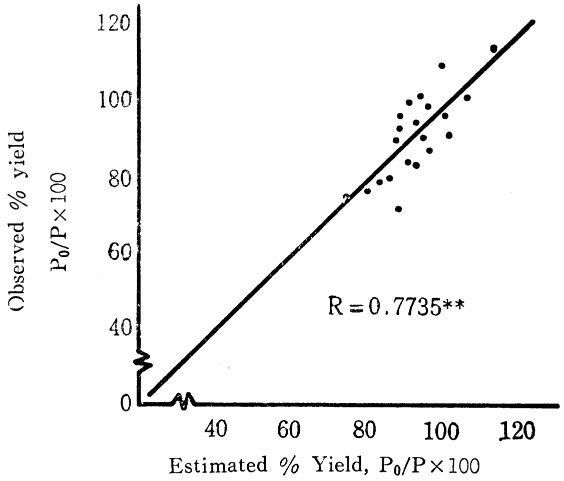

圖 1. 依下列公式求得觀察值與估計值之關係

Fig. 2. Dot chart showing observation and estimation for equation：

$\hat{Y}_1 = 2.535a - 0.1398a - 79.18c + 42.58c^2 + 5.819ac - 43.96b + 430.9$

a=clay, % b=pH, c=Bray P_1, ppm

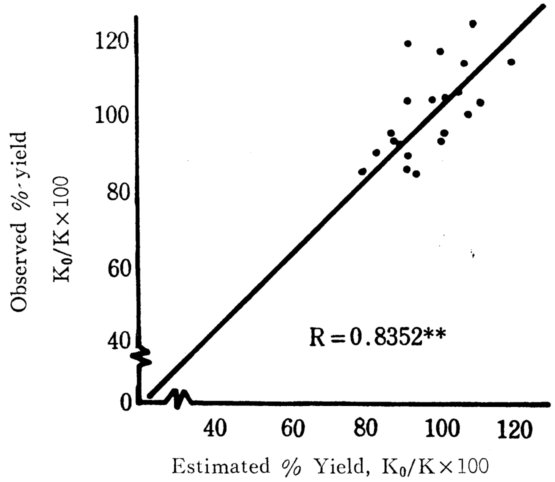

圖2. 依下列公式求得觀察值得與估計值之關係

Fig. 2. Dot chart showing observation and estimation for equation：

$\hat{Y}_2 = 1.284a + 0.124a^2 + 0.4059d + 0.0002009d^2 - 0.03402ad - 97.15b + 828.6$

a=clay, % b=pH d=Exchangeable K, ppm

爲瞭解在何種情形之下，需要施用磷鉀肥，將假設之土壤 pH 值，粘土及磷鉀含量分別代入該公式中，求出理論或估計之高粱種實收量百分率如表4，其中顯示當土壤 pH 值在 7.7 以下時，勿

表 4. 磷鉀速測值配合土壤 pH 值與粘土含量值估計高粱種實收量百分率

Table 4. Predicated percentage yield responses for a range of combination of test values

Bray P_1 ppm	Clay %	pH	Predicated[a] % yield $P_0/P\times100$	Exchangeable K ppm	Clay %	pH	Predicated[a] % yield $K_0/K\times100$
0	20	7.7	87.2	50	10	7.7	109.6
		8.1	69.6			8.1	70.7
0.2	20	7.7	96.3	100	10	7.7	114.4
		8.1	78.7			8.1	75.5
0.4	20	7.7	108.9	150	10	7.7	120.2
		8.1	91.3			8.1	81.3
0.6	20	7.7	124.8	200	10	7.7	127.0
		8.1	107.3			8.1	88.1
0.8	20	7.7	144.2	250	10	7.7	134.8
		8.1	126.6			8.1	95.9
0	15	7.7	99.0	50	5	7.7	102.4
		8.1	81.4			8.1	63.5
0.2	15	7.7	102.3	100	5	7.7	115.7
		8.1	84.7			8.1	76.8
0.4	15	7.7	109.0	150	5	7.7	129.9
		8.1	91.4			8.1	91.1
0.6	15	7.7	119.4	200	5	7.7	145.3
		8.1	101.8			8.1	106.4
0.8	15	7.7	132.7	250	5	7.7	161.6
		8.1	115.1			8.1	122.7

a. $\hat{Y}_1=2.535a-0.1398a^2-79.18c+42.58c^2+5.819ac-43.96b+430.9$

$\hat{Y}_2=1.284a+0.124a^2+0.4059d+0.0002009d^2-0.03402ad-97.15b+828.6$

Where $\hat{Y}_1=\%$ yield $(P_0/P\times100)$, $\hat{Y}_2=\%$ yield $(K_0/K\times100)$

a=clay, %, b=pH, c=Bray P_1 ppm, d=exchangeable K ppm

論土壤中所含磷鉀多寡，施用磷鉀肥多屬無效，僅在土壤 Bray P_1 含量在 0～0.2ppm 時例外，又當土壤值在 8.1 以上，施用磷鉀肥多數有效，其效果大小，則視粘土及土壤中磷鉀多寡而定，一般言之，當土壤 pH 在 8.1，粘土含量在 15～20 %，土壤中 Bray P_1 少於 0.6 ppm 時，施用磷肥有效，其次爲土壤粘土含量在 5～10%，土壤中交換性鉀在 250 ppm 以下時，施用鉀肥有效。至於磷鉀肥施用量應瞭解當地高粱可能獲得之平均單位面積收量，次將施肥增收百分率換算爲高粱種實收量，最後由投資肥料價值與預估高粱種實增收價值相比，可估計施肥是否可獲得利潤。Colwell 氏[5] 主張直接採用單位面積收量於校正模式中，藉可直接換算施肥是否有利，作者亦曾嘗試，未獲成功，可能 Colwell 氏所採用之資料爲在澳洲 Northern New South Wales 之49處小麥磷肥施用量試驗，各地磷肥施用量分爲 4 — 5 平準，小麥收量多隨磷肥施用而增加，顯示小麥對於磷肥效應

極爲顯明，相對地，減弱其他干擾因子，而澎湖農業環境欠佳，地力差異又大，直接採用單位面積收量，更加强干擾因子的影響，故以採用收量百分率間接換算施肥是否可獲得利潤爲佳，由於採用複相關模式的可靠度與資料來源有密切的關係，因此所採樣本必須可代表該地區者，本文所得之複相關模式中以土壤 pH ，粘土以及有效態磷鉀含量與高粱對於磷鉀肥效應有密切的關係，因此，今後選地進行複檢時，除注意磷鉀含量外，尙須重視土壤 pH 與粘土含量之分佈情形，俾使求得之校正模式，可獲得更普遍的應用。

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Fertility status and response of sorghum to PK fertilizers in the soils of Pescadores Islands[1]

Char-fen Lin[2]

Summary

To clarify the response of sorghum to PK fertilizers, twenty-four field trials involved five treatments with four replications in a randomized block were conducted on soils derived from weathering basalt rock on the Pescadores Islands. These soils may be divided into three groups : wind eroded soil, residual soil, and upper eroded soil with residual soil underneath.

Judging from the fertility status of the soils studied, it indicated that the depth of solum of residual soils was rather uniform at 90 cm or so. However a wide variation in solum (30-90cm) was found in the other two soils. The ranges of soil pH and the content of organic matter were at 7.7-8.1 and 0.5-1.5%, respectively. Almost all soils contain more than 70% of sand in the surface soils. Although these soils contain abundence of sand and low level of organic matter, there was a wide range in cation exchange capacity (3-33 me/100 gm). The available phosphorus index measured by Bray method (0.025N HCl-0.03N NH_4F) was extremely low, usually less than 1 ppm P. On the other hand, a wide range in exchangeable K(54-538 ppm K) was found in the surface soils. In general, the fertility level of these soils was ranked in the following order : wind eroded soil, upper eroded soil with residual soil underneath and residual soil. Consequently, the average yields of sorghum obtained from wind eroded soils were higher than those from the other two soils.

The relationship between percentage yield and soil PK tests were improved by participating the constituents of soil pH and clay in the calibration equation. The fitting models of multiple regression equation were found as follows :

$$Y_1=2.535a-0.1393a^2-79.18c+42.58c^2+5.819ac-43.96b+430.9 \cdots\cdots \quad (1)$$

$$Y_2=1.284a+0.124a^2+0.406d+0.0002d^2+0.034ad-97.15b+828.6 \cdots\cdots \quad (2)$$

where Y_1 refers to the predicated percentage yield from $P_0/P\times100$ and Y_2 from $K_0/K\times100$. From the equations, it indicated that at the soil pH lower than 7.7, mostly no profitable return will be obtained by PK-application except in the case where soil available P was lower than 0.2 ppm. However, when soil pH was greater than 8.1, the responses of sorghum to PK fertilizers will be depended on the contents of clay and levels of soil PK. The predicated percentage yield responses for a range of combination of the test values were discussed in the paper.

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水稻行株距對褐飛蝨與其捕食性蜘蛛發生之影響[1]

邱瑞珍　陳炳輝[2]

摘要：本試驗自民國 67 年第二期作開始，連續 4 期作在本所試驗田進行水稻不同行株距對褐飛蝨與其天敵，兩種捕食性蜘蛛之發生密度以及水稻產量等之影響。水稻之行株距分別爲 20×15、25×25、30×30 及 35×35 cm。

試驗結果顯示第一期作因褐飛蝨發生數量少，各處理間均無顯著差異；67 年與 68 年之第二期作均顯示褐飛蝨在 20×15 cm 處理區之平均每分蘗上族羣數較 30×30 或 35×35 cm 兩處理區爲多。再就水稻不同生育期褐飛蝨之族羣觀之，在水稻分蘗期以前，寬植 (30×30 與 35×35 cm) 與密植 (20×15 cm) 區之飛蝨發生量均無顯著差異。但進入孕穗期後，密植區之褐飛蝨族羣迅速上升。

又觀各處理區內褐飛蝨之天敵，捕食性蜘蛛如六點狼蛛 *Lycosa pseudoannulata* (B. et S.) 與裂頭小盤蛛 *Oedothorax insecticeps* (B. et S.) 之發生數，無論在第一或第二期作，自孕穗期後，寬植區稻叢上之蜘蛛數均比密植區爲多，而且兩處理區之蜘蛛數差異顯著。

稻褐飛蝨 *Nilaparvata lugens* (Stål) 乃本省與東南亞洲各地最重要之稻作害蟲，其成災與否常受稻田用藥不當，水稻品種以及其他田間耕作方式如增施肥料、正條密植以及灌排水等因素之影響(5,6,12,13)。若就水稻栽植密度之影響言之，水稻密植雖可使單位面積之產量提高，但密植亦能造成稻株間之環境通風不良，陽光照射不足，病、蟲容易孳生因而無法達到增產之效果(3,14)。據菲律賓國際稻米研究所 (IRRI) 報告，水稻種植行株距若爲 10×10 cm，則其平均每分蘗上褐飛蝨之族羣數較行株距 50×50 cm 者爲多(9)。可見褐飛蝨之發生與水稻栽植之疏密程度有關。但本省尚乏此類有關資料，筆者等爲瞭解目前本省所推行之水稻栽植密度，對褐飛蝨及其捕食性天敵蜘蛛如六點狼蛛 (簡稱狼蛛，*Lycosa pseudoannulata*) 與裂頭小盤蛛 (簡稱盤蛛，*Oedothorax insecticeps*) 族羣發生之影響，乃進行本試驗。期能找出最適宜之行株距，使稻田環境有利於害蟲捕食性天敵之生存，而不利於褐飛蝨之棲息與增殖，因而得以充分發揮害蟲天敵之生物防治效果，同時也能兼顧及稻作產量之提高，提供本省水稻栽培與稻褐飛蝨綜合防治之參考。

材料與方法

本試驗自民國 67 年第二期作開始，在臺中縣霧峰鄉本所農場設置試驗田 0.1 ha，於稻作生長全期不施用任何殺蟲劑。供試之稻種爲臺農 67 號。種植行株距分別爲 20×15 (密植區)、25×25 (普植區) 及 30×30 與 35×35 cm (寬植區) 等 4 處理。每處理均重複 4 次，共 16 小區。每小區面積爲 40 m^2。試驗田之管理按慣行方式進行，每叢插植稻苗 3 株。67 年第二期作於 8 月初插

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秧；68 年第一期作於2月中旬、第二期作於7月底插秧；69 年第一期作於2月初旬插秧。自插秧後 20 天開始調查，每隔 10 天調查1次，調查時使用目測法。爲減少誤差，所有調查工作均由1人專責進行。調查時儘量避免驚擾，而且迅速報出捕食性蜘蛛與褐飛蝨之成蟲與若蟲數，另由1人在旁記錄。最後計算每叢稻之分蘖數。每小區逢機調查20叢，分別記錄稻株之分蘖、褐飛蝨、狼蛛及盤蛛等數量。收穫時計算各小區之稻穀產量，先秤濕穀重，晒乾後秤重再換算每公頃產量。調查結果均用鄧肯氏多變域測驗法5％顯著水準分析，以比較水稻不同行株距間之差異。

又本試驗爲能確切表示水稻不同行株距試驗小區之葉面覆蓋情形，乃於 69 年一期作進行調查4種不同行株距小區之葉面積指數 (Leaf Area Index)。該調查於水稻挿秧後 20 天開始，每隔 10 天 1 次，按 K. A. Gomex 氏之計算方法[7]，每小區逢機調查 10 叢稻株，分別計算各叢之分蘖數，然後取其中間之 1 分蘖，按公式求得各葉片之面積，再合計各葉片面積之總和，而求得該分蘖之葉面積與每叢稻株之葉總面積，計算出各小區之葉面積指數。

結　　果

稻田調查結果顯示，68 年與 69 年之第一期作因褐飛蝨發生量少，各處理間之差異不顯著。67 年或 68 年之第二期作，各處理平均每分蘖之褐飛蝨密度均以密植區 (20×15 cm) 最高，而寬植區之兩處理，30×30 與 35×35 cm 最低，尤其在褐飛蝨發生盛期時兩者間之差異更爲顯著。但在褐飛蝨發生密度較低時，普植與寬植兩處理間均差異不顯著 (表 1,2)。

表 1. 稻作不同行株距對褐飛蝨發生之影響 (67年二期作)

Table 1. Effect of different rice spacings on the occurrence of brown planthoppers in the paddy field (2nd crop, 1978)

行株距 Spacing (cm)	每分蘖蟲數 (No. of BPH/tiller)						
	September				October		
	8	15	22	29	6	13	20
20×15	0.13 a	0.20 a	0.29 a	2.18 a	3.29 a	2.23 a	0.39 a
25×25	0.07 b	0.16 ab	0.21 ab	1.53 b	2.28 b	1.69 b	0.31 a
30×30	0.06 b	0.14 b	0.13 b	0.71 c	1.31 c	1.18 bc	0.18 a
35×35	0.06 b	0.13 b	0.15 b	0.65 c	1.56 c	0.95 c	0.24 a

顯著水準 5％ (P. S. 5%)

表 2. 稻作不同行株距對褐飛蝨發生之影響 (68年二期作)

Table 2. Effect of different rice spacings on the occurrence of brown planthoppers in the paddy field (2nd crop, 1979)

行株距 Spacing (cm)	每分蘖蟲數 (No. of BPH/tiller)					
	September			October		
	7	17	27	8	18	28
20×15	0.065 a	0.73 a	0.40 a	0.76 a	2.74 a	3.95 a
25×25	0.041 b	0.38 b	0.25 b	0.30 b	1.26 bc	2.68 b
30×30	0.016 b	0.24 b	0.24 bc	0.33 b	1.40 b	2.69 b
35×35	0.007 b	0.18 b	0.12 c	0.21 b	0.81 c	1.89 c

顯著水準 5％ (P. S. 5%)

在稻叢上二種捕食性蜘蛛，六點狠蛛與裂頭小盤蛛之出現均以寬植區（35×35 cm）最多，其在 67 與 68 年第二期作水稻生育中期後之稻叢上密度均比密植區（20×15 cm）高而且差異顯著（表 3,4）。

表 3. 稻作不同行株距對蜘蛛類發生之影響（67年二期作）

Table 3. Effect of different rice spacings on the occurrence of spiders in the paddy field (2nd crop, 1978)

行株距 Spacing (cm)	每 20 叢 蜘 蛛 數 (No. of BPH/tiller)					
	September	October				November
	29	6	13	20	27	3
20×15	9.8 a	4.3 a	8.0 a	9.8 a	6.0 a	6.5 a
25×25	16.3 a	9.8 a	14.0 b	20.8 b	13.3 b	13.5 b
30×30	20.5 a	20.8 b	17.5 bc	22.3 b	18.0 b	18.0 b
35×35	18.8 a	18.8 b	22.5 c	29.8 c	24.0 b	27.0 c

顯著水準 5%（P. S. 5%）

表 4. 稻作不同行株距對蜘蛛類發生之影響（68年二期作）

Table 4. Effect of different rice spacings on the occurrence of spiders in the paddy field (2nd crop, 1979)

行株距 Spacing (cm)	每 20 叢 蜘 蛛 數 (No. of BPH/tiller)					
	September			October		
	7	17	27	8	18	28
20×15	4.8 a	7.3 a	3.3 a	7.0 a	4.3 a	2.8 a
25×25	2.8 a	11.5 ab	6.5 ab	13.0 ab	10.3 ab	8.0 a
30×30	5.0 a	18.0 b	8.5 b	21.3 bc	13.8 b	9.5 a
35×35	8.3 a	17.5 b	14.0 c	26.5 c	22.3 c	22.3 b

顯著水準 5%（P. S. 5%）

表 5. 不同行株距之水稻產量比較（67—69年）

Table 5. A comparison of grain yield of different rice spacings (1978–1980)

行株距 Spacing (cm)	每公頃產量 (kg/ha)			
	一期作 (1st crop)		二期作 (2nd crop)	
	1979	1980	1978	1979
20×15	7,352 a	6,705 a	3,630 a	5,465 a
25×25	6,810 ab	6,502 a	4,110 a	4,565 b
30×30	6,177 c	6,605 a	3,830 a	4,180 b
35×35	6,320 bc	5,837 a	3,470 a	3,890 b

顯著水準 5%（P. S. 5%）

上表之調查結果顯示， 67 年二期作 20×15 cm 區之產量較 25×25 或 30×30 cm 區爲低；而在褐飛蝨發生較少之 68 年一、二期作，則以 20×15 cm 區之產量爲各處理之冠。

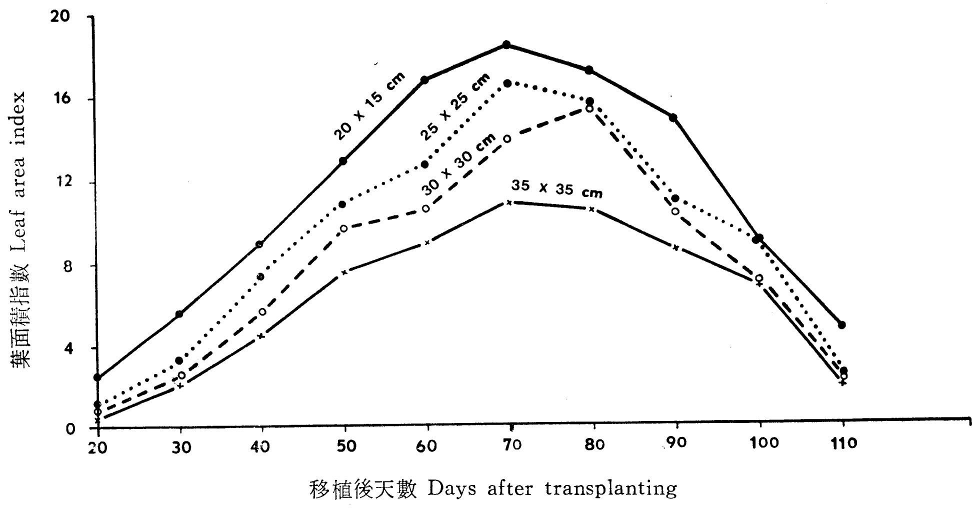

圖 1. 不同行株距水稻之葉面積指數（69年一期作）

Fig. 1. Leaf area index of Tainung 67 rice at different spacings during the first crop of 1980

上圖顯示密植區（20×15 cm）種植水稻叢數最多，其在單位面積上之葉片數亦最多，故其葉面積指數最高，依次爲 25×25，30×30 及 35×35 cm 等處理區。

討　　論

就褐飛蝨之發生而言，水稻以不同行株距種植時，除 68、69 年之第一期作因褐飛蝨發生量少，各處理差異不顯著外， 67 年與 68 年第二期作之調查結果，均顯示密植處理區（20×15 cm）平均每分蘖之褐飛蝨蟲數均較寬植之 30×30 或 35×35 cm 處理區爲多。此項結果與 IRRI 之試驗結果相近 [9,10]。 Suenaga 氏於 1963 年在日本指出同一品種之水稻，在不同之栽植密度下，褐飛蝨之發生數亦有差異 [16]。而 Pillai 等氏亦認爲在印度水稻行株距爲 10×10 cm 時，其每平方公尺範圍內之稻株上褐飛蝨之蟲數較行株距 20×20 與 20×10 cm 者爲高 [15]。水稻栽植愈密則褐飛蝨之發生愈多，二者間關係密切 [6,11]。

本試驗調查結果顯示，在水稻生育初期褐飛蝨之發生密度在寬植與密植稻株上並無顯著差異。可能因爲此時稻株生長尚小，莖葉未達茂密，即使在密植處理區仍有足够之空間可以通風透光，故密植與寬植之稻株生長環境無多大懸殊，在一般情形下，其時褐飛蝨之發生數量少，不同行株距之稻作上褐飛蝨發生數量差異不顯著。但自稻株進入孕穗期後，田間之褐飛蝨族羣隨即上升，屆時稻株之生長已極茂盛，尤其密植區爲繁茂之莖葉所密密覆蓋，陽光無法充分透射至稻株基部，乃造成通風不良高溫多濕之特殊環境，頗適於褐飛蝨之孳生 [1,13]。 Heinrichs 認爲若在此時施用液狀殺蟲劑，很難噴洒在褐飛蝨羣棲之稻株基部 [8]； Nishida 認爲水稻密植所形成之陰濕環境，頗不利於稻蝨類寄生性天敵之活動，因此密植稻作上稻蝨之被寄生率常較低 [12]。這些都是密植區褐飛蝨增殖迅速之原因。

六點狼蛛與裂頭小盤蛛通常活躍於本省稻田 ，其捕食對象以褐飛蝨與僞黑尾葉蟬 *Nephotettix cincticeps* (Uhler) 占絕大多數 ，故此等蜘蛛乃被認爲稻蟲之有效天敵 。東南亞各國亦認爲其控制褐飛蝨之效果值得重視。 1979 年 12 月 31 日，香港之 Hongkong Standard Monday 報導我國

大陸湖南等省產稻地區，發現捕食性蜘蛛乃稻蝨之有效天敵，且稱其對稻蝨之捕食效果極佳。本省之狼蛛即屬其中之一種，筆者等以爲對本省稻田捕食性蜘蛛，狼蛛與盤蛛在稻作不同行株距之田間發生情況加以瞭解，實有助於褐飛蝨之生物防治效果之探討。由本調查結果顯示，無論第一或第二期作，在水稻生育中期以後，此兩種蜘蛛之發生密度均以寬植區比密植區爲多，因有關捕食性蜘蛛之詳細資料尚感不足，有待進一步之研究。但從調查結果似可推定此等捕食性蜘蛛較喜在寬植之稻株環境下棲息。

從稻作產量觀之，水稻密植雖可提高單位面積產量，但褐飛蝨在密植之環境下增殖迅速，容易造成「蝨燒」而使稻作減產。如 67 年第二期作密植區之產量較普植 (25×25 cm) 或寬植 (30×30 cm) 爲低，此與 Pillai 等氏之報告相符 [15]。在褐飛蝨發生較少之季節，如 68 年之第一與二期作，密植區之產量爲各處理之冠，而且遠比寬植區或目前所推廣之普植區爲高。可見稻作密植時單位面積之總株數與總穗數均可增加，因而提高產量 [2,3,4]。不過密植之稻株生長環境亦有利於褐飛蝨之孳長，却不利於天敵之活動。若同時考慮害蟲、天敵及稻作產量等三項因素，筆者等認爲在褐飛蝨經常發生較少之地區或期作，似可密植以求提高稻作產量。反之，在褐飛蝨經年發生嚴重之地區或期作，種植水稻則仍以普植式 (25×25 cm) 爲佳。

本試驗選用目前本省栽培面積最廣之臺農 67 稻種，該稻種在田間栽培時顯示雖不算是抗褐飛蝨品系但對於褐飛蝨之忍受性頗強。又其對稻熱病雖屬感性稻種，但亦較易復元。依本試驗之產量結果分析，68 年與 69 年度之第一期作與 68 年之二期作產量均以密植區 (20×15 cm) 爲最高。僅 67 年第二期作因褐飛蝨之發生密度過高，部分試驗區有蝨燒現象，故其產量因而降低 (表 5)。

又依 67 年二期作迄 69 年一期作之年平均產量分析結果，除 67 年二期作外，均顯示密植區之產量最高 (表 5)。作者等乃認爲在本省中部地區之第一期作行株距可用 20×15 cm。而二期作因褐飛蝨發生密度較高，必要時需要施藥防治，故爲施藥操作方便起見，水稻行株距仍以 25×25 cm 爲合適。總之，本試驗之稻作產量係基於稻種與行株距相配合，且田間完全不施用藥劑。此後若能參酌實際需要而加施對褐飛蝨有防治效果而對捕食性蜘蛛較爲安全之藥劑，則稻作產量尙可望提高。

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Effect of rice plant spacing on the population density of brown planthopper and two predacious spiders[1]

Shui-chen Chiu[2] and Bing-huei Chen[3]

Summary

The effect of rice plant spacing on the occurrence of brown planthopper (BPH) *Nilaparvata lugens* and two predacious spiders, *Lycosa pseudoannulata* (B. et S.) and *Oedothorax insecticeps* (B. et S.), were studied at the paddy field in the Taiwan Agricultural Research Institute, Wufeng, Taichung. The experiment was begun from the second crop of 1978 to the first crop of 1980, and Tainung 67 rice was planted at 4 different spacings, viz. 20×15, 25×25, 30×30 and 35×35cm. No significant difference was found from the first crop of 1979 because of the low occurrence of BPH. And all the results were based on the records obtained from the second crops of 1978 and 1979.

Before rice tillering stage, the population densities of BPH in the 4 different spacing plots were similar to each other. However, during the booting stage, the density of BPH in the closest spacing plots (20×15cm) increased much faster than those in the other spacing plots. Evidently, the difference of rice plant spacings influenced the population growth of BPH only after the plant size itself reached a certain density threshold. The final results indicated that the plots of 20×15cm had more BPH per tiller than the plots of 30×30 and 35×35cm.

After the beginning of rice booting stage, the population densities of both *Lycosa* and *Oedothorax* spiders were significantly higher in the widest spacing plot (35×35cm) than those in the closest spacing plot (20×15cm). Which indicated that the close spacing environment is not suitable for the predacious spiders.

We conclude that the rice yield of the close spacing plot (20×15cm) is the highest if the density of BPH is low, and the yield of the currently used spacing (25×25cm) is the highest when the density of BPH is high.

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Insecticide resistance study in *Plutella xylostella* L.

I. Developing a sampling method for surveying[1]

Edward Y. Cheng[2]

Abstract : A sampling method for surveying the insecticide-resistance in diamondback moth, *Plutella xylostella* L. has been developed in a large vegetable growing area in Taiwan. We identified a diamondback moth population which was homogeneous in the permethrin resistance and the coverage of this population was about five thousand hectares. The result indicated that the diamondback moth has the ability in mixing their different genetic strains in a quite large area. The fact made us believe that the distribution pattern survey of insecticide-resistance in diamondback moth served a real significance in the future pest management study of this pest. Based on the analysis of the data obtained, we further considered that sampling diamondback moth in five separated cruciferus fields in an area of five thousand hectares was both economical and accurate in measuring the insecticide resistance.

Alarmed by rapid increase in registered insecticides and the development in insecticide-resistance in diamondback moth, *Plutella xylostella* L. [6,8,9], Taiwan Agricultural Research Institute has initiated a resistance survey program ; its purpose being to evaluate the present status of insecticidal control of the cruciferus pests. A detailed map of resistance distribution pattern is most desirable for this purpose but it can not be prepared without designing a suitable sampling method for it. In this study, we have tried to develop an economical and accurate sampling method to fulfill our need. Recently, Liu et al [7] reported that diamondback moth had developed resistance to synthetic pyrethroids in most of vegetable growing area. We intended to select an important vegetable producing area to be our model for studying and developing the sampling method. Permethrin, a synthetic pyrethroid, is our model insecticide for resistance test. Besides, we have selected cartap, an insecticide with different mode of action from permethrin, as a comparing compound.

Materials and Methods

Site selection : Hsihu-Yungchien was chosen as the location for our model in studying

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insecticide resistance survey. Because it is the largest vegetable producing district in Taiwan ; vegetables are grown year-round and insecticides are constantly and intensively used. We divided the whole area into four regions from northwest to southeast and the distance from region to region is about four to five kilometers. At the center of each region, we sampled four spots and each sampling spot is an independent cruciferus field, the distance between two sampling spots is one hundred to two hundred meters. A detailed map of regions and sampling spots is shown in Fig. 1 ; the letter (A to D) indicates

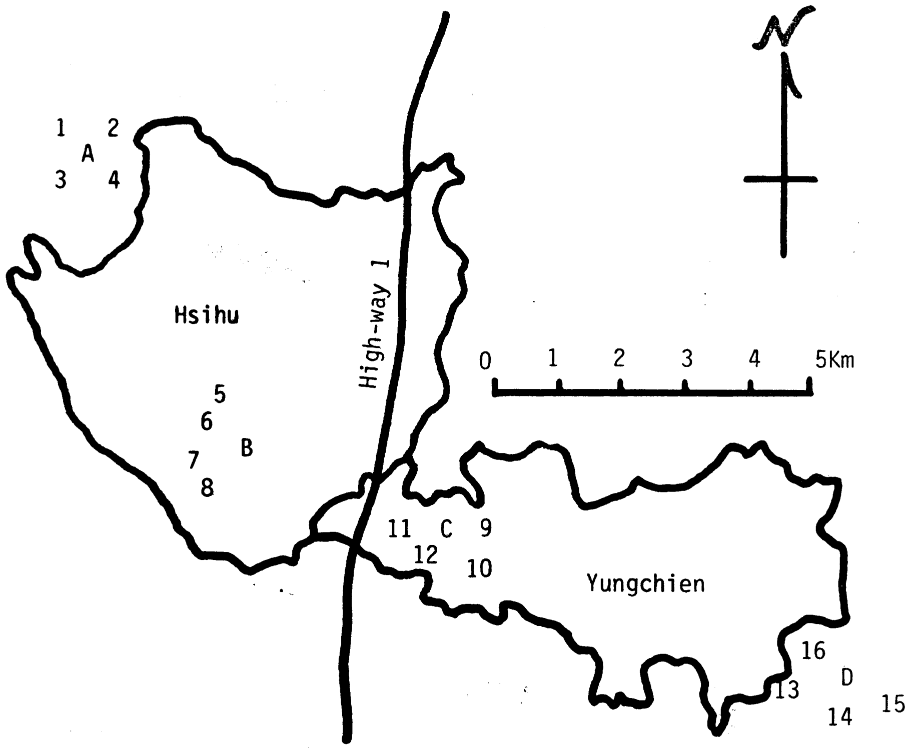

Fig. 1. The detailed map of sampling location and regions in Hsihu-Yungchien area.

the region and the number (1 to 16) represents the sampling spot.

Insects and insecticides : In each sampling spot, we collected two hundred to three hundred diamondback moth larvae or pupae. Insects were brought back to the laboratory and were reared on insecticide-free cabbage to the adult stage ; the adults were fed with honey-water mixture daily. After mating, females oviposited their eggs on a potted cabbage in the screen cage. Only the third instar larvae of F_1 generation of collected specimen were used in the insecticide LC_{50} test, and the insecticide treatment was conducted in a Potter Spray Tower. Cartap and permethrin were chosen to test all sixteen samples and both chemicals were obtained in 95% technical grade from industrial suppliers.

Cartap was dissolved in a mixture of acetone and water (1 : 1, v/v) and permethrin was dissolved in acetone only. In spraying operation, one milliliter of insecticide solution was first pipetted into the holding tube of Tower, then we switch on the spray control,

the solution was sucked into a stainless steel U-tubing and sprayed out from the nozzle into the tower. After the spray, we waited for ten seconds before lowering the stage to take out the objects. The holding tube was rinsed throughly two to three times with a proper solvent whenever we changed the insecticide or the concentration. In the permethrin test, insects were put on a sheet of paper and sprayed with insecticide directly, then they were released on a piece of fresh cabbage leaf in a petri dish. A total of eleven different concentrations of permethrin ranged from 1,200ppm to 11,700ppm were used in the test. In the cartap test, insects were not sprayed with insecticide directly; instead they were fed with a piece of throughly sprayed cabbage leaf in a petri dish. Likewise, eleven different concentrations of cartap ranged from 150ppm to 6,000ppm were used. Ten to fifteen third-instar diamondback moth larvae were treated in one replica and results of three replicas were sumed together for probit analysis. The insect mortality of each treatment was counted twenty-four hours after the spray; the post-treatment holding temperature and relative humidity were controlled at 28±1.5°C and 80±5% respectively.

Analysis: The toxicity data in LC_{50} of all samples were subjected to the F-test for examining the significant difference among regions. Since the arrangement of regions were relative in a line which extended from A to D, the analysis also followed that order. If the difference among region A to D was significant, further tests were carried out on region A to C and on region B to D separately, and this procedure was continued until the coverage of a homogeneous population was identified. Since the chemical control intensity of sampling spot may influence the population density of natural enemies, the rate of parasitism was examined and tabulated according the sample location. The parasitism data were subjected to the same analysis procedure as the toxicity data.

Results

The insecticide sensitivity of diamondback moth, *Plutella xylostella* L., from Hsihu-Yungchien to permethrin and cartap are assembled in Table 1 and 2 respectively. Field

Table 1. The permethrin susceptibility of *Plutella xylostella* sampled from four regions in Hsihu-Yungchien area.

Field	LC_{50} of sampled *P. xylostella* (ppm)			
	A	B	C	D
1	3,820	—[a]	5,830	2,415
2	2,653	7,662	4,560	4,854
3	6,207	5,223	4,837	3,590
4	6,533	7,646	4,836	3,143
Average[b]	4,803	6,844	5,016	3,501

a. not enough insects for the LC_{50} test.

b. the laboratory strain has a LC_{50} value at 93 ppm.

Table 2. The cartap susceptibility of *Plutella xylostella* sampled from four regions in Hsihu-Yungchien area.

Field	LC_{50} of sampled *P. xylostella* (ppm)			
	A	B	C	D
1	520	649	796	623
2	560	506	547	687
3	336	299	503	320
4	503	421	703	704
Average[a]	480	469	637	583

a. the laboratory strain has a LC_{50} value at 345 ppm.

strains of diamondback moth have significantly higher LC_{50} value than the laboratory strain in the permethrin test and the range varied from 26 to 82 times. These results confirmed that the diamondback moth population in Hsihu-Yungchien had developed resistance to permethrin which is a rather universal phenomenon in the whole area, in spite of the fact that the level of resistance might be different from region to region as our analysis later indicated.

In the cartap test, the difference of insecticide susceptibility between the field strains and the laboratory strain was not comparable to the permethrin test. It was either that cartap resistance had not yet developed in diamondback moth or there was no real susceptible strain at all to compare with. The rate of parasitism of *Apanteles plutellae* in the diamondback moth is presented in Table 3 and those data had through the arcsin transformation prior to the analysis.

Table 3. Per cent of parasitism of *Plutella xylostella* sampled from four regions in Hsihu-Yungchien area.

Field	Per cent of parasitism of *P. xylostella*			
	A	B	C	D
1	19.2	1.8	6.7	31.0
2	10.0	5.8	1.6	16.5
3	19.2	5.6	4.0	39.1
4	6.1	4.0	13.8	19.1
Average[a]	13.6	4.3	6.5	26.4

a. parasitized by *Apanteles plutellae*, the major larval parasite of *P. xylostella* in Taiwan.

The F-test results of the permethrin-susceptibility, the cartap-susceptibility and the rate of parasitism of diamondback moth in regard to region A to D are presented in Table 4 ; the significant difference level is set at 5%. These results showed that the field

Table 4. The F-test results of the permethrin susceptibility, the cartap susceptibility and the percentage of parasitism of *Plutella xylostella* sampled from four regions in Hsihu-Yungchien area.

Regions	P>F value		
	Permethrin sus.	Cartap sus.	Percent of parasitism[a]
A-B-C-D	0.0429*	0.3191	0.0021*
A-B-C	0.1794	—[b]	0.0655
B-C-D	0.0078*	—[b]	0.0020*

* significant at 5% level.

a. percent of parasitism was tested through the arcsin transformation.

b. further test was not necessary.

strains of diamondback moth from region A to C were homogeneous in both of their permethrin-susceptibility and the rate of parasitism, and all four region's diamondback moth was homogeneous in their captap susceptibility.

In an attempt to examine the relationship between the chemical control intensity and the density of natural enemies in general, we paired the data of Table 1 and 3 for a correlation test. We established a negative correlation between the permethrin-resistance and the rate of parasitism from all samples ; the correlation is significant with the correlation coefficient at −0.57134 and the P> | R | value at 0.025. In order to minimize the sample size to save both time and labor but without critically reducing the information accuracy, we grouped the permethrin-susceptibility data in region A to C and the cartap susceptibility data in the whole area separately as two information pools. Then the

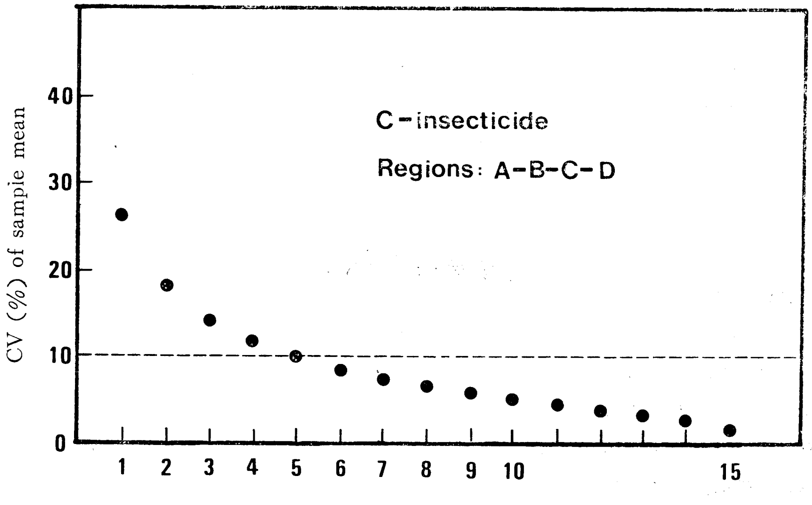

Fig. 2. The relationship of the coefficient of variation (CV) and the sample size from pooled data of cartap susceptibility of *Plutella xylostella* in A-B-C-D region of Hsihu-Yungchien area.

coefficient of variation was tested against the sample size by sampling the information pool and the permethrin data pool containing eleven data and the cartap data pool containing sixteen data. The results were presented in Fig. 2 and 3 ; both tests showed that the coefficient of variation of the sample mean was close or lower than 10% if the sample size increases to five. In other words, by tolerating a coefficient of variation of

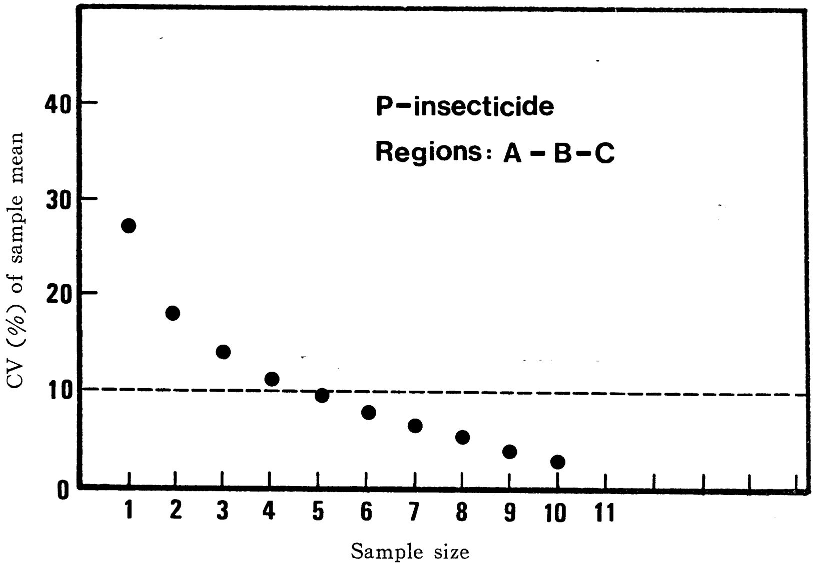

Fig. 3. The relationship of the coefficient of variation (CV) and the sample size from pooled data of permethrin susceptibility of *Plutella xylostella* in A-B-C region of Hsihu-Yungchien area.

sample mean at 10% in both data pools then we can save more than 50 to 68% of time and labor in sampling. Region A to C covers about five thousand hectares and sampling five independent cruciferus fields was adequate in measuring the insecticide-susceptibility of a supposed homogeneous population of the diamondback moth.

The region D was actually surrounded by rice paddy and was not similar to three other regions in the sense of cropping system. The test result confirmed that it's diamondback moth population was less resistance to permethrin than those from other regions.

Discussion

Not only the reports [5,9] but also the field observation in several important vegetable growing areas have convinced us that diamondback moth is the most destructive insect pest on the cruciferus in Taiwan. The constant occurrence of diamondback moth is also a main reason which drives the farmers to adapt an intensive chemical spraying schedule. The early success of chemical control, as it was introduced, has created itself an irreplaceable image for farmers that it is the sole effective measure for the pest control. Even when one insecticide gradually lost its original efficacy, the farmers learned quickly to shift to a new insecticide and not even bother to ask the reason. After twenty years or more in depending only on the chemical control, the diamondback moth

has developed resistance to many insecticides as other investigators reported [1,2,3,4,6,7]. A periodic survey of insecticide resistance in the diamondback moth is urgently needed to identify the troubled regions and their specific problems. Although Chi and Sun [3], Feng and Sun [4], Lee and Lee [6] made field investigations in diamondback moth resistance but none of them had ever designed a sampling method for surveying the distribution pattern of resistance. The study is intended to fulfill the need of an economical and suitable sampling method in surveying a large area. From the results we obtained and the report of Liu et al [7], diamondback moth has clearly developed resistance to permethrin and our data indicated that there are two diamondback moth populations in Hsihu-Yungchien with different permethrin-resistance levels. The first population which covered region A to C has higher resistance than the second population in region D.

Because the coverage of the first population is larger than most of other vegetable concentrated growing areas on the island, developing a proper sampling method in this area will serve well for most of other needed areas as well.

The coverage of first population also indicated that the diamondback moth has the ability in mixing their genetic strains in a quite large area, so surveying the distribution pattern of insecticide resistance in diamonback moth has a real significance in the pest management study.

By examining the overall results, we maintain a general view of our model area i. e., the region A to C is a perennial vegetable cultivating area with high intensity insecticide usage and low natural enemy density. The region D is mostly a rice producing region and the vegetable growing is sporadical, the insecticide usage is less intensive and the natural enemy density is higher than region A to C. The diamondback moth in the whole area has not developed serious resistance to cartap yet, and the homogeneity in their cartap-susceptibility does not necessarily mean that they are homogeneous in other aspects as well. From our analysis, we believe that by sampling diamondback moth in five separate cruciferus fields in an area of five thousand hectares are both economical and accurate in measuring the insecticide resistance.

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小菜蛾抗藥性之研究

I. 調查方法之探討[1]

鄭 允[2]

中文摘要

爲建立本省各蔬菜產地小菜蛾（*Plutella xylostella* L.）抗藥程度測定體系，必須了解小菜蛾抗藥品系空間分布與距離之關係，從而決定正確的取樣距離與頻度。此研究係在溪湖、永靖地區約140 平方公里範圍之蔬菜栽培區，每隔四至五公里，設置樣本區一處，全區共設立四個樣本區，每一樣本區取樣四個採集點，各點相距約一至二百公尺，均爲獨立之十字花科菜田，共計十六處採集點，將所採得小菜蛾幼蟲及蛹携返室內，用不噴殺蟲劑之甘藍菜飼養，取其第一代三齡幼蟲，測定其對培丹及百滅靈的半量致死濃度，再將所得資料按區排列，以變方分析不同區間樣本之差異。尋得具共同抗藥程度之族羣後，再比較小菜蛾樣本數與平均值之機差關係，由此一關係訂定最經濟的取樣數，但以不嚴重影響統計値的正確性爲原則，在此，吾人訂定之容許機差爲 10 %，取樣量爲五個樣本點。因爲研究結果顯示抗藥族羣具相同抗藥力者可涵蓋五千公頃之廣，亦小菜蛾有相當的能力不斷地混合田間的生理小種，樣本點相距數百公尺之差異不大，而在無障礙物時此一現象尤其一致，因此在五千公頃範圍之蔬菜專業區內，只需獨立取樣五點，即可測出有代表性的抗藥程度，供預測之用。

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1. 臺灣省農業試驗所 研究報告 第996號。本研究爲中央加强農建補助計劃〔70農建-5.1-產-47 (02)〕，承農業發展委員會及省農林廳補助，賴宗賢及周桃美協助研究工作，謹此致謝。

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Jour. agric. Res. China (中華農業研究) 30(3) : 285~293 (1981)

Insecticide resistance study in *Plutella xylostella* L.

II. A general survey (1980-81)[1]

Edward Y. Cheng[2]

Abstract : A general survey of resistance in diamondback moth, *Plutella xylostella* L., to five commonly used insecticides in Taiwan was conducted from December 1980 to April 1981. Started from northeast down to southwest of Taiwan, along the west coast, we had sampled twenty-one districts; two adjacent districts were approximate twenty kilometer apart.

The highest resistance ratio was 32.5 for carbofuran, 10.9 for mevinphos, 3.6 for cartap, 48.5 for permethrin and 75.0 for fenvalerate. Geographically, the resistance problem was more serious in south than the north and the high ground regions were less troubled than the intensively cultivated vegetable growing areas.

In an overall analysis of both the intensity and the complexity of resistance in the diamondback moth, we found that out of all the districts which were investigated, 19% with serious trouble, 47% with some problems, 24 % with minor problem and only 10% without significant resistance problem.

Practically, the diamondback moth, *Plutella xylostella* L. has developed resistance to almost all the insecticides which were recommended in controlling this pest in Taiwan. A thorough understanding of the problem will help a great deal to plan a better pest management program in the near future. Taiwan Agricultural Research Institute has developed a suitable sampling method for surveying the resistance of diamondback moth in a rather large area[2]. The general survey of resistance was conducted from December 1980 to April of the following year. Five commonly used insecticides were tested for the resistance level ; a general view of insecticide usage in the diamondback moth control were evaluated as well.

Materials and Methods

The diamondback moth was collected from each sampling district following the sampling

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method which we had established previously [2]. Total of two to three hundred of matured larvae and pupae were collected from five separated cruciferous fields within a limit of five thousand hectare. Insects were brought back to the laboratory and reared on insecticide-free cabbages to the adult stage ; the adults were fed with honey-water mixture daily. After mating , females oviposited their eggs on a potted cabbage in the screen cage. Only the third instar larvae of F_1 generation of collected insects were used in the LC_{50} determination and the insecticide treatment was conducted in a Potter Spray Tower.

Started from northeast (IL-strain) down to southwest (LY-strain) of Taiwan, along the west coast, we had sampled twenty-one vegetable growing districts (Fig. 1) ; two adjacent districts were approximate twenty kilometer apart.

We selected carbofuran, cartap, fenvalerate, mevinphos and permethrin for this investigation because they were officially recommended insecticides for the diamondback moth control in Taiwan. Carbofuran and mevinphos in commercial formulated products were diluted in water to different concentrations for the test.

Cartap, fenvalerate and permethrin were obtained from industrial suppliers in 95% technical grade. For the test, cartap was dissolved in a mixture of acetone and water (1 : 1, v/v) ; fenvalerate and permethrin were dissolved in acetone.

In spraying, one milliliter of insecticide solution was pipetted into the solution-holding tube of the tower ; when we switch on the spraying control, the solution was sucked into a stainless steel U-tubing and sprayed out from the nozzle into the tower. After spraying, we waited for ten seconds before lowering the stage to take out the objects. The solution-holding tube was rinsed throughly two to three times with a proper solvent whenever the concentration or the insecticide was changed.

In testing carbofuran or mevinphos, one side of a cabbage leaf was sprayed with insecticide first and then we loaded insects on the other side of leaf and sprayed again. In cartap test, insects were not sprayed, instead they were fed with a piece of throughly sprayed cabbage leaf. In the tests of fenvalerate and permethrin, only the insects were sprayed with insecticides.

For any insecticide LC_{50} determination, approximate ten concentrations were tested on each sample population.

Twenty third-instar larvae were used in one replica with two replicas for each concentration ; the sum of two replicas were subjected for the probit analysis. The insect mortality was counted twenty-four hours after the treatment and the post-treatment condition was controlled at 25 ± 1°C and 80 ± 5% in relative humidity.

In calculating the resistance ratio, the IL-strain was used as the susceptible strain because it was more susceptible than the laboratory strain [2] to all five tested insecti cides.

When we mapped the resistance distribution pattern, the resistance ratio were graded into five classes according to its magnitude and they were 1-2, 2-5, 5-10, 10-20 and 20 plus.

Results

The complete results of this survey was presented in Table 1. It is clear that the diamondback moth has developed resistance to insecticides in most of places and the resistance level were alarmingly high in some regions. The highest resistance ratio was 32.5 for carbofuran, 10.9 for mevinphos, 75.0 for fenvalerate, 3.6 for cartap and 48.5 for permethrin. Since the samples were equally distanced and covered the whole west coast of Taiwan, it is possible to take an average of all samples to examine the overall situation ; the averaged ratio was 10.125 for carbofuran, 4.47 for mevinphos, 2.185 for cartap, 34.12 for fenvalerate and 19.5 for permethrin.

Table 1. The resistance of twenty-one field strains of diamondback moth, *Plutella xylostella* L. to five commonly used insecticides .

Field location	Level of resistance									
	Carbofuran		Cartap		Fenvalerate		Mevinphos		Permethrin	
	LC_{50}[a]	RR[b]	LC_{50}	RR	LC_{50}	RR	LC_{50}	RR	LC_{50}	RR
IL —	42	1.0	250	1.0	134	1.0	64	1.0	104	1.0
ST —	1,367	32.5	531	2.1	7,546	56.3	332	5.2	4,624	44.5
SH —	279	6.6	536	2.1	526	3.9	90	1.4	334	3.2
TY —	212	5.0	455	1.8	1,165	8.7	109	1.7	568	5.5
CP —	499	11.9	406	1.6	3,323	24.8	255	4.0	904	8.7
ML —	236	6.7	527	2.1	1,907	14.2	284	4.4	751	7.2
TC —	434	10.3	382	1.5	4,579	34.2	304	4.8	1,248	12.0
TT —	250	6.0	679	2.7	2,443	18.2	271	4.2	1,139	11.0
PL —	280	6.7	368	1.5	2,820	21.0	265	4.1	895	8.6
SL —	327	7.8	895	3.6	1,603	12.0	201	3.1	556	5.3
HH —	258	6.1	542	2.2	3,815	28.5	321	5.0	5,041	48.5
HL —	469	11.2	558	2.2	5,289	39.5	412	6.4	3,991	38.4
PC —	162	3.9	481	1.9	4,322	32.3	251	3.9	1,346	12.9
MH —	208	5.0	531	2.1	4,612	34.4	190	3.0	1,360	13.1
PT —	339	8.1	526	2.1	9,690	72.3	330	5.2	2,545	24.5
HY —	358	8.5	646	2.6	9,448	70.5	193	3.0	2,243	21.6
MT —	213	5.1	647	2.6	8,724	65.1	303	4.7	1,227	11.8
LC —	836	19.9	723	2.9	5,700	42.5	699	10.9	3,792	36.5
KS —	343	8.2	414	1.7	3,134	23.4	224	3.5	1,237	11.9
NP —	649	15.5	420	1.7	755	5.6	219	3.4	2,034	19.6
LY —	736	17.5	687	2.7	10,055	75.0	477	7.5	4,705	45.2

a. concentration of insecticide (in ppm).

b. resistance ratio to the IL-strain.

The resistance intensity in regard to the sample location was mapped in **Fig. 1** to 5. In these figures, we can find the coverage and the intensity of resistance in different field strain of diamondback moth. We further examined the survey results in a correlati on test and the test result proved that there were strong correlation among the resistance intensity of different insecticides from the same sample site. This fact indicated that not only the intensity but also the complexity of chemical control had contributed to the

resistance problem.

In order to examine the overall situation, we designed an analysis system to demonstrate the combined effect of intensity and complexity of resistance. In this system, we averaged the resistance rating of cartap, carbofuran, mevinphos and synthetic pyrethroid as one combined single rating. The synthetic pyrethroid rating was the average of fenvalerate and permethrin. The result was presented in Table 2 and the values were ranged from 1.0 to 3.75 ; again they were classified into four sub-ranges of 1-1.75, 1.75 -2.50, 2.50-3.25 and 3.25-4.00 and we artificially defined them as properly, frequently, intensively and overly in the insecticidal usage for the diamondback moth control. The rating in relation to the sample location was mapped in Fig. 6, in hoping to gain a better understanding of their geographic distribution pattern. The IL-strain and TY-strain both belonged to the group with least problem in resistance ; the SH-strain, the PL-and SL-strain combination, the PC-strain and the KS-strain belonged to a same group with minor resistance problem ; three mostly troubled regions emerged in the map were the areas covered by the ST-strain, the HL-strain and a rather spread out region which harbored the LC-strain and LY-strain. Rest of investigated regions formed the largest group with some problems in resistance in the diamondback moth control.

Table 2. The combined rating of intensity and complexity of resistance in twenty-one field strains of diamondback moth. *Plutella xylostella* L. in Taiwan.

Field location	Resistance rating in intensity				Overall average	
	Carbofuran	Cartap	Mevinphos	Syn. pyrethroid		
IL —	1	1	1	1	1.00	P
ST —	5	2	3	5	3.70	O
SH —	3	2	1	2	2.00	F
TY —	2	1	1	3	1.75	P
CP —	4	1	2	4	2.75	I
ML —	3	2	2	4	2.75	I
TC —	4	1	2	5	3.00	I
TT —	3	2	2	4	2.75	I
PL —	3	1	2	4	2.50	F
SL —	3	2	2	3	2.50	F
HH —	3	2	2	5	3.00	I
HL —	4	2	3	5	3.50	O
PC —	2	1	2	5	2.50	F
MH —	2	2	2	5	2.75	I
PT —	3	2	3	5	3.25	I
HY —	3	2	2	5	3.00	I
MT —	3	2	2	5	3.00	I
LC —	4	2	4	5	3.75	O
KS —	3	1	2	4	2.50	F
NP —	4	1	2	4	2.75	I
LY —	4	2	3	5	3.50	O

P : properly F : frequently I : intensively O : overly in insecticide usage.

Discussion

In 1975, Chang [1] first reported that the diamondback moth had developed resistance to organophosphorus insecticides in Taiwan and the resistance ratio was ranged 7.6-19.4 for mevinphos, 3.3-11.7 for DDVP, 7.7-9.0 for malathion and 6.0-6.3 for parathion. Lee and Lee [5] continued the study and reported that the ratios were ranged 2.0-16.0 for malathion, DDVP, diazinon, elsan, and mevinphos. Chi and Sun [3] reared a susceptible strain to determine the diazinon resistance and the highest level they measured was 14.0 which coincided with the highest resistance in the field strain. Although the resistance in tobacco budworm have increased 200 folds toward methyl-parathion [7] ; the same situa tion has not happened in the diamondback moth yet because the resistance to organopho sphates in the diamondback moth reported so far has not reached 20 folds. The simi larity of both Lee and Lee's report and our survey has demonstrated that the resistance of diamondback moths to organophosphates can or has reached an equilibrium in the field condition. Since Lee and Lee's result also indicated that there were similarity among the level of resistance to five organophosphates of different strains ; the survey result of mevinphos may also reflect what was happened to most of other organo phosphates. In the case of carbamate, Feng and Sun [4] had studied the methomyl resistance and reported that ratio was ranged from 2.8 to 14.0 with an average of 8.0.

In our study, the resistance for carbofuran was some what higher and the ratio was ranged from 3.9 to 32.5 with an average of 10.1. Although the relationship between the resistance mechanisms of carbofuran and methomyl is not clear so far, the resistance level of carbamates were two folds of those for the organophosphate ; in other words, the diamondback moth can develop a higher resistance to carbamates than organophosphates in field without much of explanation yet.

In the aspect of synthetic pyrethroid, the magnitude of resistance is much higher than both carbamate and organophosphate ; Liu et al [6] described that a field strain of diamondback moth gained 207 folds of resistance to fenvalerate, and the highest resista nce for permethrin, cypermethrin and decamethrin can also reasch 14.1, 87.3 and 67.1 respectively. Our survey indicated the same phenomenon that is the diamondback moth possess ability to develop higher resistance toward synthetic pyrethroids and the highest resistance ratio measured is 75.0 for fenvalerate and 48.5 for permethrin. Obviously, the resistance mechanism to synthetic pyrethroid may be different from those for ca rbamate or organophosphate. Although it is too early to deal with the so called distri bution pattern of resistance in concerning with any particular insecticide but some continuity of the resistance level can be found in Table 1 and Fig. 1-5. Several resistance-proned regions can be easily located on the maps ; based upon this fact that some kind of mapping system might able to be developed in the near future for monito ring and forecasting the resistance situation. Just as we had expected in our first study [2], cartap is the least resistance-troubled insecticide and the result of this survey proved that the diamondback moth has not developed serious resistance to this insecticide yet.

One surprising finding emerged from this study is that the insecticide resistance of diamondback moth is definitely a localized problem. As the IL-strain demonstrated that it was the most susceptible strain to all five tested insecticides ; on the other hand, several other field strains possessed strong resistance to almost all five tested insecticides. This fact matched the habit of most vegetable farmers who usually sprayed the field by mixing several insecticides together. Our speculation is further confirmed by a correlation test. We believe the map which represents both intensity and complexity of insecticide usage in the diamondback moth control will help a great deal in the future pest management design. The survey result will also directs the residue monitoring agency to concentrate their effort in the areas where insecticide was heavily used.

APPENDIX

Name Index of Sample Location.

IL-	I-Lan	宜蘭	HL -	Hsi-Lo	西螺
ST-	Sheh-Tzu	社子	PC -	Pao-Chung	褒忠
SH-	Shan-Hsia	三峽	MH-	Min-Hsiung	民雄
TY-	Ta-Yuan	大園	PT -	Pu-Tzu	朴子
CP-	Chu-Pei	竹北	HY -	Hsin-Ying	新營
ML-	Miao-Li	苗栗	MT-	Ma-Tou	麻豆
TC-	Ta-Chia	大甲	LC -	Lu-Chu	路竹
TT-	Tan-Tzu	潭子	KS -	Kao-Shu	高樹
PL-	Pu-Li	埔里	NP -	Nei-Pu	內埔
SL-	Shui-Li	水里	LY -	Lin-Yuan	林園
HH-	Hsi-Hu	溪湖			

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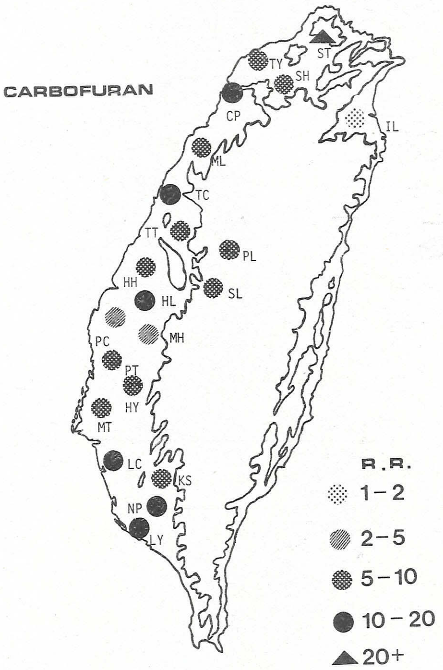

FIG. 1 THE GEOGRAPHIC DISTRIBUTION OF CARBOFURAN RESISTANCE IN THE DIAMONDBACK MOTH IN TAIWAN, 1980-81.

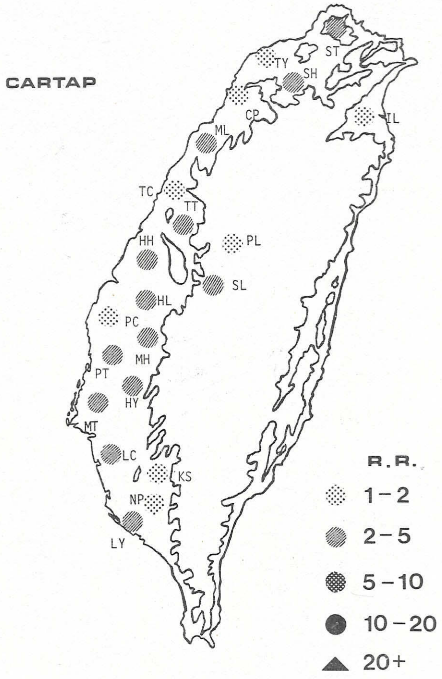

FIG. 2 THE GEOGRAPHIC DISTRIBUTION OF CARTAP RESISTANCE IN THE DIAMONDBACK MOTH IN TAIWAN, 1980-81.

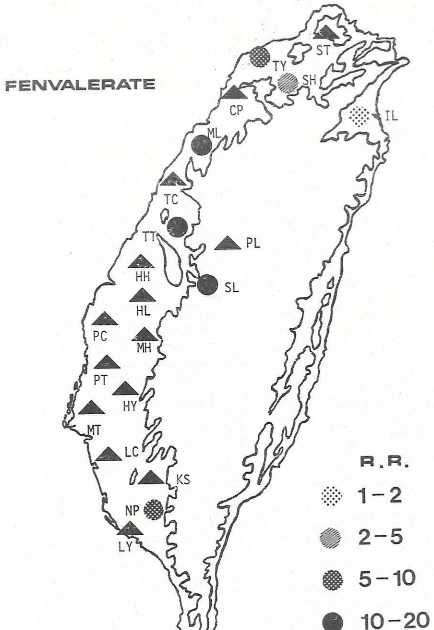

FIG. 3 THE GEOGRAPHIC DISTRIBUTION OF FENVALERATE RESISTANCE IN THE DIAMONDBACK MOTH IN TAIWAN, 1980-81.

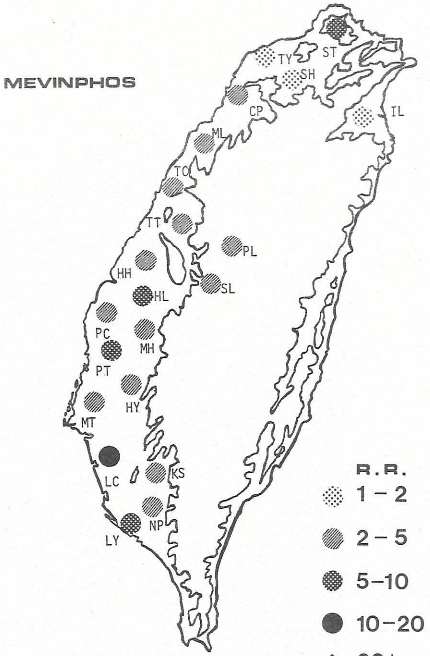

FIG. 4 THE GEOGRAPHIC DISTRIBUTION OF MEVINPHOS RESISTANCE IN THE DIAMONDBACK MOTH IN TAIWAN, 1980-81.

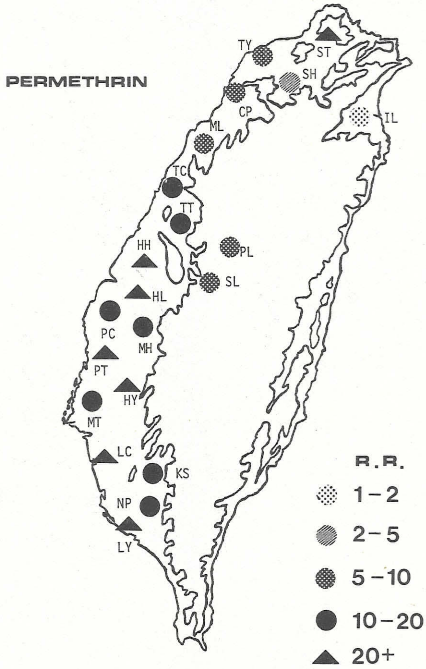

FIG. 5 THE GEOGRAPHIC DISTRIBUTION OF PERMETHRIN RESISTANCE IN THE DIAMONDBACK MOTH IN TAIWAN, 1980-81.

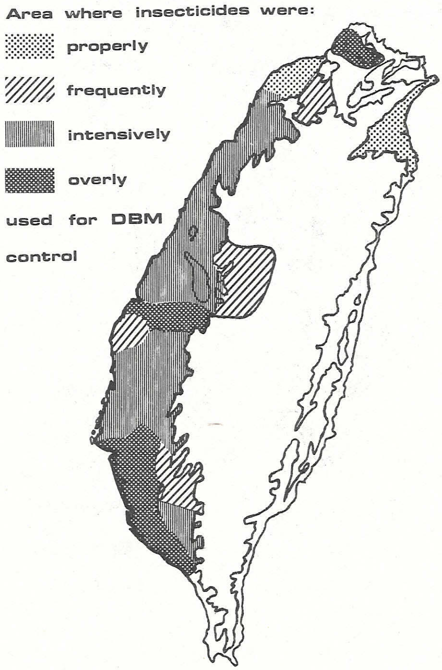

FIG. 6 THE COMBINED RATING OF BOTH INTENSITY AND COMPLEXITY IN THE DIAMONDBACK MOTH RESISTANCE TO INSECTICIDES IN EVALUATING THE CHEMICAL CONTROL MEASURE OF DIFFERENT LOCATIONS.

小菜蛾抗藥性之研究

Ⅱ. 全省調查結果及討論[1]

鄭　　允[2]

中 文 摘 要

本所爲確實瞭解全省各地小菜蛾（*Plutella xylostella*）對現用殺蟲劑之反應，特於民國69年12月至70年4月間，進行抗藥性調查。執行計劃時，將全省自宜蘭至林園劃分爲21區，不含東部及梨山，於各地區依適當之取樣程序，採集小菜蛾樣本携返室內，測定其抗藥程度。測定用之殺蟲劑爲加保扶（氨基甲酸鹽類）、美文松（有機磷類）、培丹（有機氮）、百滅靈及芬化利（合成除蟲菊精類）等五種，均爲目前推薦於小菜蛾之殺蟲劑。結果顯示，各地區品系之抗藥程度，若以宜蘭品系爲基準，則抗加保扶程度爲1至32倍、抗美文松程度爲1至11倍、抗培丹者爲1至4倍、抗百滅靈者爲1至48倍、而抗芬化利者則爲1至75倍。抗藥性程度之地理分佈，除北部社子地區外，由北而南漸見嚴重。宜蘭品系對五種供試藥劑之感度均高，路竹及林園品系之抗性則偏高而且普遍。接近山區者則抗性較低，而專業區內之小菜蛾，均具較高抗性。若將每一地區樣本對各類殺蟲劑抗性高低及其普遍性混合計算時，可推算該地區農民用藥之頻度及其種類混雜程度。推算結果就小菜蛾抗藥性而言，全省19%地區殺蟲劑使用過度而有嚴重之抗藥問題，47%地區殺蟲劑使用頻繁有高程度抗藥性問題，24%地區殺蟲劑使用應屬例行性，僅具中度抗藥性，而10%地區殺蟲劑使用適當，屬低抗藥性問題困擾地區。

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1. 臺灣省農業試驗所 研究報告 第 999 號。本研究爲中央加速農建補助計劃〔70 農建-5.1-產-47(02)〕承農業發展委員會及省農林廳補助研究經費，賴宗賢及周桃美協助研究工作，謹此致謝。

2. 本所應用動物系研究員。臺灣省 臺中縣 霧峰鄉。

中華農業研究 (Jour. agric. Res. China) 30(3)：294～302 (1981)

人工飼養及放射能照射對東方果實蠅影響之研究[1]

鄭 允 宋艷香[2]

摘要：本研究乃就本省應用「不孕性昆蟲釋放技術」，防治東方果實蠅 (*Dacus dorsalis* Hendel) 時，所釋放之東方果實蠅品質，進行探討。研究結果指出，現行之人工飼養過程不影響羽化率，但使成蟲羽化後之存活率降低，並縮短成蟲壽命。現用 13 krad 伽瑪放射能處理蠅蛹後，羽化率、成蟲羽化後之存活率及成蟲壽命均受不利影響。羽化後三日內，成蟲之飼養受空間限制很大，在高密度時，成蟲大量死亡，原因為蛻蛹之成蟲無法覓得安靜處所，完成正常羽化過程。若以隔板增加飼養箱之有效附着面積，使擁擠程度降低，即可提高成蟲之存活率。雄性成蟲飛翔肌中所含七種代謝酵素之活性，均未因人工飼養及 13 krad 伽瑪放射線處理而改變。因此，其飛翔生化機能似不受上述兩種處理之影響。

本省自民國 64 年起，由美國農部，夏威夷果實蠅研究室 (Hawaiian Fruit Flies Laboratory)[3] 引入"不孕性雄蟲應用技術" (Sterile Male Technique)，試行防治東方果實蠅 (*Dacus dorsalis* Hendel)。其過程為，東方果實蠅先經人工飼養，大量繁殖後 (1,21)，於蛹期接受 13 krad 的鈷-60 伽瑪放射能照射，破壞蟲體的生殖系統機能 (5)，再將羽化之伽瑪線處理蠅釋放於田間，待伽瑪線處理蠅與野生蠅交尾後，使後者產生無效卵，從而達到防治果蠅之目的。

目前，伽瑪線處理蠅可在地面或空中釋放，地面釋放時，係將蠅蛹裝入網中，掛於果園任由羽化之成蟲自行飛散。空中釋放則先將蠅蛹放入羽化箱中，俟其羽化後，飼以食物及水，3 日後，移入 5°C 之冷藏室內，將成蟲裝入釋放器，運交飛機進行空中釋放。就上述過程中，甚多操作方法及環境因素可降低所釋放昆蟲之生存率及品質，若能加以改進，當可大幅提高防治效果。Chambers (7) 曾就人工飼養所得昆蟲之品質，有一完整的回顧及討論，而 1980 年環球昆蟲學會第十六屆大會，亦以伽瑪線處理蠅品質問題為其主要議題。

以往已有許多學者研究果實蠅類 (Tephritidae) 經人工飼養及鈷—60 等處理後之生理及品質上的改變。Keiser 及 Schneider (12,13) 認為經鈷-60 處理之雌蟲壽命較未處理者長，但雄蟲間則無差別，並發現，若於羽化時及時供給糖與水份，可減少羽化後之死亡率。Rossler (17) 發現人工飼養所得之地中海果實蠅 (*Ceratitis capitata*)，其雌蠅所需之產卵前期 (preoviposition period) 較野生蠅短，但兩者間之壽命長短並無區別。Kakinobana (11) 發現若以瓜實蠅 (*Dacus cucurbitae*) 作比較，則人工飼養蠅產卵早，卵量多，性成熟早，交尾之日週期性 (diurnal rhythm of mating) 亦較早，但性競爭力及飛翔能力均仍與野生蠅相近。Balock 等 (5) 測定，若初齡幼蟲接受 2.5 krad 的劑量照射，雖然有86%可化蛹，但是其羽化率只有12%。Harris 等 (10) 測量羽化殘廢率隨箱中裝

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1. 臺灣省農業試驗所 研究報告 第 1000 號・本文為行政院國家科學委員會補助研究計畫，編號 NSC-69B-0409-21(01)。研究工作承王惠娟、黃明道協助進行，謹此致謝。
2. 本所應用動物系研究員、計畫助理。臺灣省 臺中縣 霧峰鄉。
3. 現已改名為熱帶果蔬研究室 (Tropical Fruit and Vegetable Research Laboratory)

蟲密度之增加而提高，但羽化率並不受密度之影響 。 Bailey [4] 以 10 krad 放射能處理，澳洲瓜實蠅（*Dacus cucumis*）之運動能力並未降低，若將劑量提高至 40，60 或 80 krad，才逐漸損傷成蟲之活動能力，此外，40 krad 處理亦顯著地降低了雄性澳洲瓜實蠅的交尾能力，而 10 krad 處理並無此差別。

本研究係就 1.飼養及放射能處理對東方果實蠅之羽化，存活及壽命的影響， 2.現用羽化箱之最大容蛹量及 3.雄蠅飛翔肌中七種代謝酶受飼養及放射能的影響 ，一一予以探討，以求改進“不孕性昆蟲應用技術”在防治東方果實蠅上的效益。

材料與方法

供試之東方果實蠅，除野生者係由蕃石榴落果中採集得來以外，人工飼養及 13 krad 鈷-60 處理者，均由臺灣香蕉研究所關西柑桔試驗場所供應，成蟲係依邱氏 [1] 之方法飼養。

一、成蟲壽命比較試驗：將未區分性別之蛹置於直徑 8.5 cm ，高 5 cm 之塑膠盒中，蓋以尼龍紗網，每盒 20 蛹，每次 5 盒，每處理重覆 3 次，成蟲羽化後，逐日更新飼料及供水並記錄其存活率，飼養溫度為 28°C。

二、羽化率與畸形發生率測定：將野生、飼養及伽瑪線處理蠅蛹分別置於，長寬高均為 30 cm 之養蟲箱中，每箱 500 蛹，每種 3 箱。俟完成羽化後 3 日，分別計數其羽化率、存活率及畸形數量。畸形者又分為已蛻蛹而發育不全者及死於蛻蛹過程中者二類。

三、飼養密度對伽瑪線處理蠅羽化及其品質之影響 ，此一測定使用兩種型式養蟲箱 ，標準箱為 $90\times30\times30\ cm^3$ ，扁箱為 $90\times30\times15\ cm^3$ ，側面及頂均為尼龍網，以便透氣與餵飼。標準箱中分別放入 4 萬、6 萬、8 萬及 10 萬蛹，4 種容蟲量，而扁箱中則分別放入 2 萬、3 萬、4 萬及 5 萬蛹，4 種容蟲量。每種容蟲量處理均重覆 3 次（箱），以逢機法安排其相對次序於養蟲架上。羽化 3 日後計算各箱中伽瑪線處理蠅羽化率，畸形發生率及存活率。

四、代謝酵素活性測定：取羽化間隔不超過 24 小時之 3 日大雄蟲 20 隻，剪取胸部，放入 0°C 之磷酸緩衝液（pH=7.3）中，先以 Polytron 打碎，再以低速離心，除去表皮及細胞殘渣，以細紗布過濾懸著液後，置於 0°C 下保存供試，共計測定七種代謝酵素活性， 分別為 glyceraldehyde-phosphate dehydrogenase，lactate dehydrogenase，glycerol-3-phosphate dehydrogenase，glycerol-3-phosphate oxidase， succinate dehydrogenase ， carnitine acetyltransferase，citrate synthase。測定方法及條件完全依照 Beenakkers [6] 方法。酵素反應係於 28±1°C 下進行，所用生化藥品全為 Sigma Co. 產品，使用之儀器為 Shimadaz 210A雙光束光譜儀。蛋白質含量則係以 Lowry [15] 方法測定，並以 BSA（bovine serum albumin）為蛋白質標準劑。

結　　果

一、成蟲壽命比較：如圖 1 所示，野生蠅最長可活 225 日，飼養蠅及伽瑪線處理蠅之生命較短，均為 180 日，而半數死亡期長，依其類別分為野生蠅 134 日，飼養蠅 29 日，伽瑪線處理蠅 23 日，差別很大。以逐月平均存活率計算，全期 8 個月平均存活率為野生蠅 46.9 %，飼養蠅 18.3 %，伽瑪線處理蠅僅 15.3 %，若以此為平均壽命之基準，則僅人工大量飼養因子即可減少東方果實蠅之壽命達 61 %，而 13 krad 的放射能再使其壽命減少所餘 39 %之中的 6.4 %。

二、羽化能力比較：此項結果與壽命比較稍有不同，羽化率並未因人工飼養而減少，但羽化後 3 日內之成蟲存活率因人工飼養而由 97 %降低為 88.6 %。放射能處理對羽化率及存活率均有不良影響（見表 1）。總結所得結果，野生蠅可由蛹回收 86.7%的存活成蟲，飼養蠅回收率降為 76.8 %，而伽瑪線處理蠅的存活成蟲回收率只有 56.2 %。

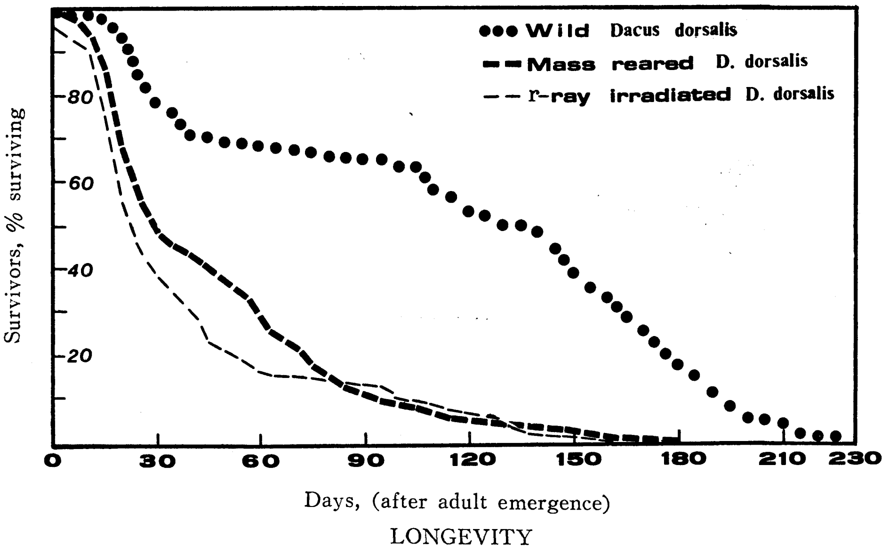

圖 1. 野生，飼養及伽瑪線處理東方果實蠅壽命之比較

Fig. 1. The survival rate of wild, mass-reared and gamma-ray irradiated oriental fruit flies, *Dacus dorsalis*

表 1. 野生，飼養及伽瑪線處理東方果實蠅 (*Dacus drosalis*) 之羽化率及存活率[a]比較

Table 1. The adult emergency rate and immediated survival rate[a] of wild, mass-reared and gamma-ray irradiated oriental fruit flies.

來源 Source	成蟲羽化率 % adult emergence	×	三日內存活率 % survived within 3 days	=	健康成蟲回收率 % return of healthy fly from total reared pupae
野生蠅 Wild	89.4		97.0		86.7
飼養蠅 Mass-reared	86.7		88.6		76.8
伽瑪線處理蠅 Irradiated	76.1		73.8		56.2

a. 指羽化後三日內之存活率。 The adult survival rate within three days after emergence.

進一步分析折損原因，見圖 2 ，野生蠅羽化後全無畸形者，飼養蠅有畸形出現，而放射能處理雖未造成更多的畸形，但顯著減弱蛻蛹的能力，提高因羽化不完全而死亡之比率。

三、飼養密度對羽化率及成蟲品質之影響：羽化率不受影響，各處理均為76%，但羽化者之存活率則隨箱中飼養蟲數之提高而降低，密度最高之成蟲存活率只有 26.22 %，較諸對照組之 73.83 % 可謂折損率太高，就其折損原因分析（見圖 2），可見擁擠的環境大量提高了畸形死亡率，亦即幼成蟲蛻蛹後，無法尋得一安靜處所完成羽化， 因而死亡。而不同飼養密度下蛻蛹不完全率均維持在 20 %上下，與對照組並無顯著差別，因此可確定蛻蛹能力不受擁擠因子影響，但的確受到放射能之損害

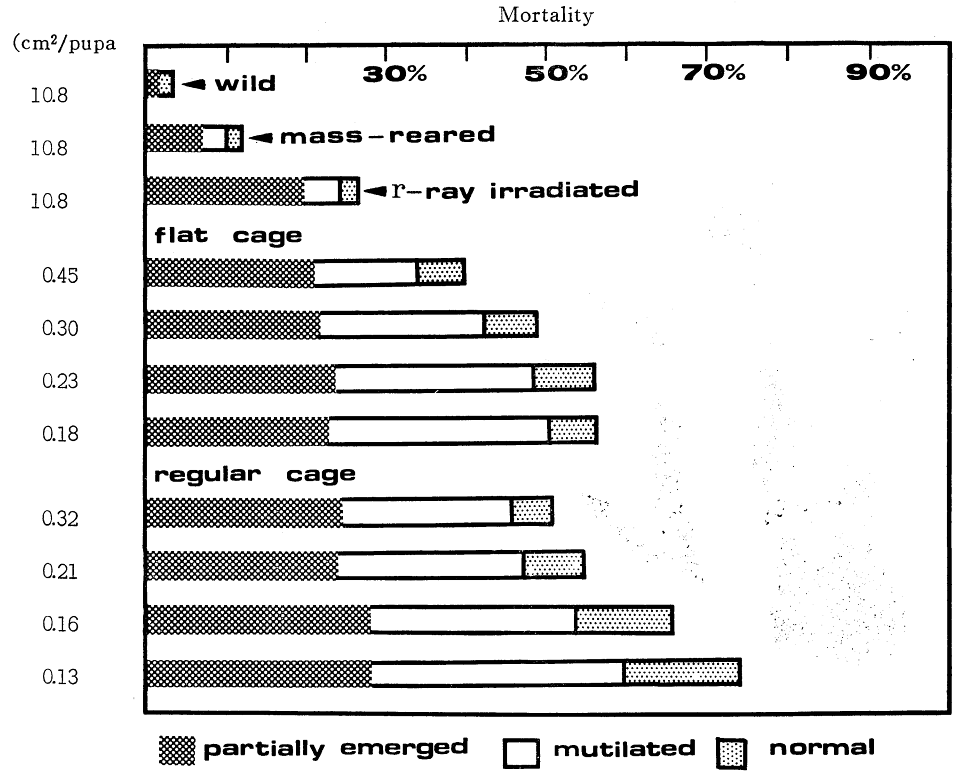

圖 2. 不同飼養空間下，東方果實蠅成蟲死亡率及其原因之比較

Fig. 2. Casualties of emerged flies in different holding conditions and from different sources.

(見結果二)。將圖2之資料以羽化箱之面積 (cm^2) 及體積 (cm^3) 分析，得到迴歸關係，如表二，顯示擁擠死亡率與表面積之關係較體積之關係密切，其迴歸方程式爲 $y=35.05-49.2x$, ($r=0.926$), y=死亡率， x=飼養密度之倒數 (cm^2/insect)，爲進一步反測以上結果之可靠性，乃於標準箱 30 公分高者中加裝隔板三片，並依隔板之高低分爲三種處理，分別爲 90×5cm，90×10cm 及

表 2. 成蟲傷殘率與飼蟲箱空間因子之迴歸關係

Table 2. The regressional correlations between the mutilation rate and various rearing spatial parameters of holding cage.

(X_i) 空間因子 Spatial parameters	迴歸方程式 The equation of regression[a]	r-value	臨界值 Critical limit[b]
箱底面積 Basal area, cm^2	Y=31.44−106.17X	0.7553	(cm^2/pupa) 0.2542
箱內總面積 Total area, cm^2	Y=35.09−49.20X	0.9264	0.6228
箱內體積 Total space, cm^3	Y=35.97−7.92X	0.7590	(cm^3/pupa) 3.6010

a. Y—% of mutilation 傷殘率

b. X value, when Y=4.45% (because the mutilation rate in check cage is 4.45%) .
此爲傷殘率等於 4.45 %時之空間因子之大小，因對照組之傷殘率爲 4.45 %。

90×15cm ，每箱裝10萬蛹，再行測定成蟲存活率，所得結果如圖三，明顯地因隔板供給了額外有效面積空間，而使成蟲存活率由不加隔板組的 22.5 %依隔板大小而回昇爲 31、38 及 48 %。

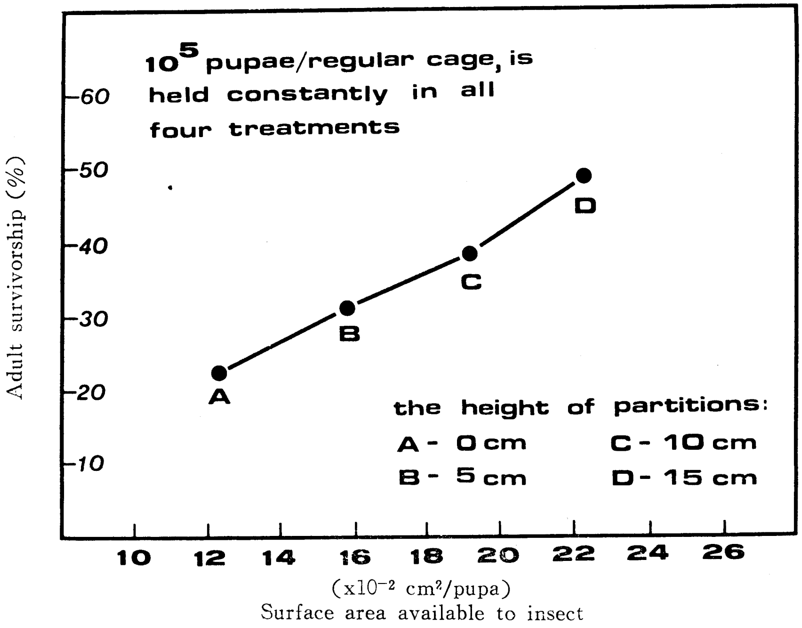

圖 3. 利用飼養箱隔板大小，增加東方果實蠅成蟲存活率之效果比較

Fig. 3. Recovering in survival rate of adult flies by providing more surface area per pupa in the holding cages.

四、雄性成蟲胸肌中能量代謝酵素活性比較：人工飼養與放射能處理均不影響七種酵素活性的高低（見表三）。並曾就其中任選 GAPDH 測定鈷-60 處理期前後，其本身變化情形，結果如圖四

表 3. 七種能量代謝酶在野生，飼養及伽瑪線處理雄蠅胸肌中活性之比較

Table 3. Specific activities of seven metabolic enzymes isolated from three day old male adult thorax of wild, mass-reared and gamma-ray irradiated *Dacus dorsalis*

	Specific activity[a,b]						
D. dorsalis	GAPDH	GP-ox	GDH	SDH	LDH	CS	CAT
野生蠅 Wild	202.0	0.69	58.0	0.76	5.81	59.7	2.13
飼養蠅 Mass-reared	239.4	0.64	61.3	0.45	3.61	63.0	1.72
伽瑪線處理蠅 Irradiated	218.7	0.59	58.2	0.49	3.31	62.5	2.08

a. specific activity = micromoles substrate/mg protein/hour

b. twenty-five thoraxes were pooled together for analysis as one sample and the result values were the average of three tests.

GAPDH : glyceraldehydephosphate dehydrogenase
LDH : lactate dehydrogenase
GP-ox : glycerol-3-phosphate oxidase
GDH : glycerol-3-phosphate dehydrogenase
SDH : succinate dehydrogenase
CS : citrate synthase
CAT : carnitine acetyltransferase

，活性變化爲一U形曲線，與多數酵素在蛹期的變化相同。此等曲線之上昇部份表示酵素正在形成，而顯示其並未受放射能的影響，應可確立 13 krad 的劑量不干擾酵素蛋白合成過程，因此伽瑪線處理蠅飛翔肌之生化作用仍屬正常。

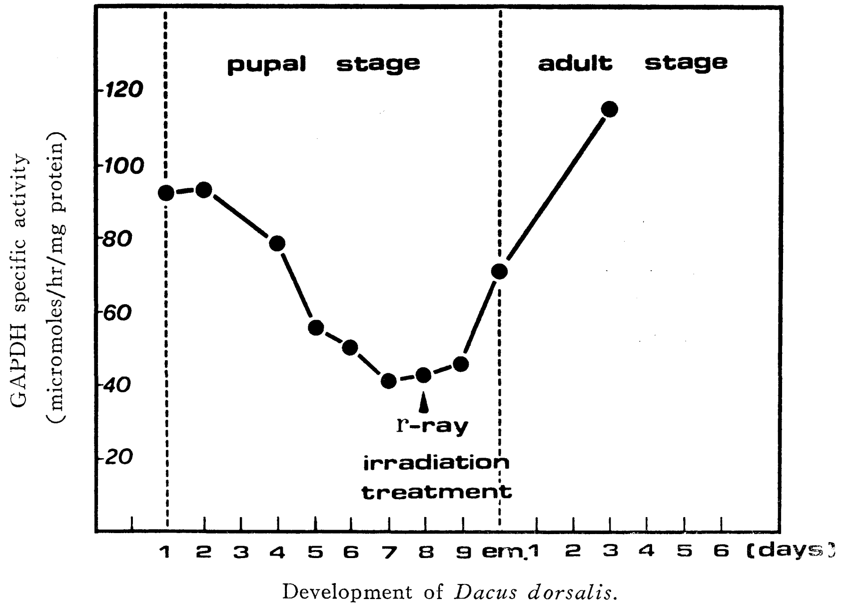

圖 4. 東方果實蠅蛹期 glyceraldehydephosphate dehydrogenase 活性之變動情形

Fig. 4. The changing pattern of glyceraldehydephosphate dehydrogenase activity in the pupal stage of oriental fruit fly, *Dacus dorsalis*

討　　論

利用釋放不孕性之昆蟲做爲害蟲防治工具，具有許多其他防治所未有的優點[14]，但就東方果實蠅防治之應用而言，可謂尚在起步階段，目前數個釋放案例，均以海中孤立之小島爲對象[9,18,20]，現在本省使用此一技術，其涵蓋面積之大小仍屬創舉。因此在執行上各種因素以及其影響之大小均需仔細研究及探明。有關田間調查方法，需用之蟲數，Steiner 提供了初步的計算方法[19]，但就各個步驟對飼養並接受鈷-60 處理之東方果實蠅所發生的影響亦應加以闡明，尋求可能之改進。

由本實驗所測得半數死亡之壽命天數，飼養蠅爲 29 天，野生蠅爲 134 天，前者與 Keiser 等[13]所得之 29～38 天相近，而後者則遠較徐氏等[2]所得 40～50 日之結果爲長，雖然 Keiser 等認爲在 15 krad 放射能處理使雌蠅之半數死亡期由 29 天延長爲 38 天，但若與野生蠅之 134 天相比，則所增加之壽命可謂不顯著，因此 Keiser 發現之差別實在無太大意義。吾人認爲造成縮短壽命之主因在於人工飼養，而其原因爲何，尚待探討。放射能照射對果實蠅的損傷，在於降低羽化率及成蟲存活率，使回收率由飼養蠅之 76.8 %降爲 56.2 %，因夏威夷僅使用 10 krad[5]，其劑量較吾人所使用者爲低，若使用 10 krad 可能可提高回收率，而近來 Ashraf[3] 及 Ohinata 等[16]報告，在氮氣中作放射能處理，可提高伽瑪線處理蠅的性競爭力，但所需之劑量較在空氣中處理高 2 倍，亦可能造成較高的死亡率。今後應就放射能處理之劑量及方式做改進，以提高成蟲之性競爭力，降低死亡率爲目標。飼養蠅中有大量畸形蠅出現之原因，可能係在人工培養環境中許多不良性狀個體，受到額外的保護而未能如在自然界中被淘汰，因此以後在計算飼養量中應先行扣除此一不良性狀部份，以免造成實際釋放量的偏差。

大量飼養昆蟲時必須測定適當的飼養密度。飼養密度過高常造成大量死亡。Harris[10] 亦曾發現空投果實蠅之紙盒可因裝蟲量增加而造成傷殘率增加，但並不因裝盒而影響其羽化率，其結論與吾人所得結果相似，由結果中顯示本省目前採用每標準箱放養 6～8 萬蛹之成蟲存活率只有 34.6～26.7%，折損率很大，若改用扁箱設計或加裝不妨礙裝蟲工作之隔板，增加有效養蟲面積，可大幅度增加存活率。

就飛翔肌中七種能量代謝酵素之活性未受飼養及放射能之影響，與 Bailey[4] 發現 10 krad 不能影響澳洲瓜實蠅 (*Dacus cucumis*) 之活動力以及 Economopoulos[8] 發現野生及伽瑪線處理橄欖蠅 (Olive fly, *Dacus oleae*) 具有相等之飛翔距離及飛散能力相符合，因此 13 krad 的放射能似尚不能對飛行肌之生理造成明顯的損傷。綜觀以上結果及參考資料，吾人認爲以下數項事實已可確立，即：

1. 人工飼養法明顯地縮短果實蠅平均壽命。
2. 13 krad 劑量的放射能減弱成蟲蛻蛹之能力及存活率。
3. 羽化箱中成蟲過多可造成大量成蟲殘廢及死亡，此類折損率可由增加箱內有效面積改進之。
4. 伽瑪線處理蠅之飛翔肌生理作用與野生蠅相似，並未因人工飼養及放射能處理而有所損傷。

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Effects of mass-rearing and gamma-irradiation on the oriental fruit fly, *Dacus dorsalis* Hendel[1]

Edward Yun Cheng and Martha Sung[2]

Summary

Currently, the sterile-insect technique is under testing in Taiwan for controlling the oriental fruit fly, *Dacus dorsalis* Hendel. In practicing the sterile-male insect releasing program, the fruit flies have to be mass-reared and then sterilized with 13 krad gamma-radiation energy. These two treatments will probably reduce the quality of fly to some degree. In order to determine the nature and extent of possible adverse effects, we compared several aspects of the mass-reared fly and the sterilized fly to the wild fly. The results indicated that both the mass-rearing method and the gamma-radiation energy caused some physical and physiological damges in released sterile flies. The apparent effects and the degree of damages are :

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(1) The mass-rearing method reduced the adult longevity by 61%, the adult emergence by 2.7% and the first three day adult survival rate by another 8.4% (Fig. 1, Table 1).

(2) The gamma-radiation at 13 krad further reduced the adult longevity by 6.4%, the adult emergence by 10.6% and the first three day adult survival rate by another 14.8% (Fig. 1, Table 1).

(3) The crowding in the holding cage before field releasing resulted in more casualties. In the actual releasing program, the healthy flies harvested from mass-reared pupae were merely 33% of total reared pupae compared with 56% in an uncrowded holding condition. The mortality in the holding cage was closely related to the size of unit surface area available to each fly. When the results were calculated on the basis of number of pupae per cage, the mutilation loss followed the equation of $Y=35.09-49.20X$, where Y is percentage of mutilation, X is the available surface per pupa in cm^2/pupa, and the minimum area per pupa required was 0.63 cm^2 before the death from mutilation occurred (Fig. 2, Table2). The survival rate can be effectively revived by increasing the available surface area in the holding cage (Fig. 3).

(4) The mass-rearing method and the gamma-radiation did not change the specific activity of seven metabolic enzymes in flight muscle of adult male fly and the enzymes tested were glyceraldehydephosphate dehydrogenase, lactate dehydrogenase, glycerol-3-phosphate dehydrogenase, glycerol-3-phosphate oxidase, citrate synthase, carnitine acetyltransferase and succinate dehydrogenase (Fig. 4, Table 3).

中華農業研究 (Jour. agric. Res. China) 30(3): 303～307 (1981)

稻細蟎藥劑防治試驗[1]

羅幹成　何琦琛　林國欽[2]

摘要：於溫室內種植臺南5號水稻，於分蘗盛期人為接種稻細蟎 (*Steneotarsonemus spinki*) 500頭／叢，孕穗初期分別施以5種農藥，每處理2重複，未施藥者為對照，每隔10日施藥1次，共施藥3次。於第一次施藥前及第三次施藥後至齊穗期分別調查稻細蟎數，至收穫時調查不稔率、穗重、千粒重、穗頸長及穗頸扭曲度等。結果顯示 Ethyl-parathion 與 Dicofol 對稻細蟎效最優，防治率分別達99.9及97.0%，不稔率分別為7.3及7.7%；而 Azomite、Diazinon 與 MIPC之防治率分別為79.5、82.9及45.0%，不稔率分別為13.5、21.3及39.8%；而對照組之不稔率則高達72.0%，又因 Ethyl-parathion 對人畜及天敵毒性劇烈，故擬推薦 Dicofol 防治稻細蟎。

自從本省於民國65年南部地區發生嚴重水稻不稔症後，經發現稻細蟎 (*Steneotarsonemus spinki*) 與其關係密切，故自66年起進行了一連串的藥劑防治稻細蟎之試驗：黃氏(1977)於室內分兩次篩選27種農藥，結果以 Nissol、Furadan 及 Torak 對稻細蟎防治效果較佳[6,8]；陳氏等亦曾於室內篩選20種藥劑，結果以 Plictran、Nissol、Cyanatox、Azomite、Kumitox、Furadan 及 Morestan 等7種藥劑殺蟎率較高[10]；後來再作不同用量試驗，結果選出Morestan、Azomite、Furadan、Chlorobenzilate 及 Torak 等五種藥劑供作田間稻細蟎防治試驗[11,12]；但經臺南及高雄改良場在田間試驗比較結果，皆未達理想防治之要求[3,9]；方氏曾於田間試驗比較5種藥劑對稻細蟎防治之效果，結果以 Ethyl-parathion 效果最優[1]；但後來經陳氏等進一步比較試驗結果，Ethyl-parathion 之殺蟎效果表現並不特別突出[9,12]。又據 Allen 等氏及 McMurtry 等氏認為細蟎類 (Tarsonemids) 雖屬蟎類，但其對農藥之反應顯與葉蟎類 (Tetranychids) 有別[14,20]；Allen 等氏曾以草莓細蟎(*Steneotarsonemus pallidus*)為對象，以50種藥劑試驗比較防治效果，結果發現防治效果最優且穩定之藥劑僅有 Azobenzene, Endrin 及 Thiodan 三種，而 Ethyl-parathion與 Diazinon 效果亦佳，但殘效期僅及1星期，多種殺蟎劑對草莓細蟎之效果反均不理想[14]；Schaefers 又對此細蟎作多種藥劑之藥效比較試驗，結果以 Endosulfan, Endrin, Telodrin, Eradex, Pentac 及 Cynem 均具理想防治效果[21]。然而上述效優之藥劑多屬有機氯烴劑，均因殘毒或魚毒之問題已遭禁止使用；Badulin 和 Lomtev 以小麥花細蟎 (*Steneotarsonemus panshini*) 為對象，此蟎在土壤中越冬，以Dimethoate, Trichlorphon或 Malathion 處理土壤可獲理想防治效果[15,16]。而本省對稻細蟎之防治經多年試驗，僅發現 Ethyl-parathion 有顯著殺蟎效果，然此藥劑對人畜毒性極劇，害蟲及害蟎對其易生抗藥性，且對有益天敵毒性強烈，故本試驗目的在選出較 Ethyl-parathion 安全而有效的藥劑，提供作為稻細蟎防治之用，以突破此一多年來未能解決的問題。

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材料和方法

本試驗於 69 年 2 至 6 月在本所溫室內進行，以空心磚砌槽，磚槽大小爲 237×79×28 cm ，內襯以塑膠布後再塡沙壤土並浸水，插植臺南 5 號水稻，每槽計 33 叢。照一般施肥及管理方法，於水稻分蘗盛期，每叢水稻人爲接種稻細蟎 500 頭，至孕穗初期（接蟎後 20 日），每叢採取 1 分蘗於雙管立體顯微鏡下調查稻細蟎密度。當日隨即施藥，供試農藥共 5 種： Ethyl-parathion 47% E. C., 稀釋 1,000 倍（華農企業股份有限公司）；Dicofol 42 % M. F. 稀釋 800 倍（美國 Rohm & Haas 公司）；Azomite 60 % E. C. 稀釋 1,200 倍（Kanesho 公司）；Diazinon 60 % E. C. ，稀釋 1,200 倍（中國農業化工股份有限公司）；MIPC 20% E. C., 稀釋 800 倍（大同農藥股份有限公司）。每種藥劑處理 2 重複，每隔 10 天施藥 1 次，共施藥 3 次，施藥時各槽均以塑膠布隔離，以防干擾相鄰之不同處理之水稻，每槽噴施藥液量爲 800～1,000 ml. ，對照處理不施任何藥劑。第三次施藥正値抽穗之前期，至水稻齊穗期，每叢再任取 1 分蘗調查稻細蟎密度，收穫後調查不稔率，穗重，千粒重，穗頸長及穗頸扭曲度等農藝性狀。

結　　果

一、藥劑對稻細蟎防治效果

於第一次施藥直前及經三次施藥後，至齊穗期調查每分蘗稻細蟎數，並根據 Abbott's formula 計算防治率，所得結果列於表 1 。明顯看出 Ethyl-parathion 和 Dicofol 對稻細蟎均具極顯著之防治效果，防治率分別高達 99.9 及 97.0 %；而 Azomite 與 Diazinon 效果較遜，但防治效果亦達 80 %左右； MIPC 效果最差，防治率僅 45 %，但與未施藥之對照組相較，其對稻細蟎仍具某種程度之壓抑作用。

表 1. 五種藥劑對稻細蟎之防治效果

Table 1. Effect of five chemicals for control of *Steneotarsonemus spinki*.

藥劑 Chemicals	施藥前蟎數 No. mites before treatment	施藥後蟎數 No. mites after treatment	防治率[a] Percentage of contrd
Ethyl-parathion 47% E. C.	217	0.3	99.9 a
Dicofol 42% MF.	141	144.5	97.0 a
Azomite 60% E. C.	140	985.0	79.5 b
Diazinon 60% E. C.	264	1,552.0	82.9 b
MIPC 20% E. C.	112	2,454.5	45.0 c
Check	162	5,562.2	0 d

a. 各欄數字之右邊英文字母，爲經 Duncan's New Multiple Range Test 之 1 %顯著度標準 ，字母相同者爲不顯著。

二、藥劑處理對水稻各農藝性狀之影響

水稻收穫時，自 33 叢水稻中任選 10 叢，每叢取樣 2 穗，調查不稔率、穗重、千粒重、穗頸長及穗頸扭曲度，所得結果列於表 2 ，各處理中以 Ethyl-parathion 與 Dicofol 處理之不稔率均最低，分別爲 7.3 及 7.7 %；千粒重亦最重，分別爲 21.77 及 21.79 g ；穗頸扭曲度亦均最小，分別僅 0.04 及 0.05。又 2 處理間穗重及穗頸長略有差異，然差異均不顯著，並且具最佳之性狀。其他藥劑處理之農藝性狀皆隨防治率之低降或稻細蟎數之增加而呈相當規律之變動。

表 2。 藥劑防治稻細蟎對水稻各農藝性狀之影響[a]

Table 2. The agronomic characteristics of rice under different chemical treatments of *Steneotarsonemus spinki.*

藥 劑 Chemicals	防治率 % control	不稔率 % sterility	穗重 Panicle weight (g.)	千粒重 1,000 grain weight(g.)	穗頭長 Length of panicle neck (cm)	穗頸扭曲度[b] Degree of twisted panicle neck
Ethyl-parathion	99.9 a	7.3 d	3.14 a	21.77 a	41.3 a	0.04 c
Dicofol	97.0 a	7.7 d	2.89 ab	21.79 a	39.9 ab	0.05 c
Azomite	79.5 b	13.5 cd	2.29 bc	17.98 b	37.6 abc	0.12 c
Diazinon	82.9 b	21.3 c	2.35 bc	17.78 bc	36.9 bc	0.42 bc
MIPC	45.0 c	39.8 b	1.88 c	15.33 c	35.9 cd	0.79 ab
CK	0 d	72.0 a	1.30 d	9.71 d	32.5 d	1.33 a

a. 同表 1 之說明，

b. 穗頸扭曲度分無扭曲之 0 級，手指感覺扭曲之 1 級，視覺可辨之輕度扭曲為 2 級，中度為 3 級，强度為 4 級此欄所列之值為20穗之平均值。

討　論

本試驗之過程皆在溫室內進行，目的在盡量減少外界影響因子之干擾，且經人為接種稻細蟎，使稻細蟎在水稻上之分佈較為均勻，並可保證稻細蟎之密度可達理想試驗之所需。在此種較單純之條件下進行此一系列之試驗，所獲之結果，所受環境條件之影響較小，而陳氏等於田間之藥效比較，雖經二次重複試驗，結果 Ethyl-parathion 並無特殊顯著之防治效果 [12]，其原因可能在當時稻細蟎密度太低，或因其他因素之影響，使其無從發揮高度之功效；而 Dicofol 為黃氏最初藥效篩選27種藥劑中之一 [6]，結果不彰之原因，可再探討，其與本試驗不同之處，可能為施藥次數之差別。

本試驗所得另一結果，是在各種藥劑處理下，由於藥效之不同，因而使各不同處理之水稻上出現不同密度的稻細蟎，此一系列不同密度的稻細蟎與不稔率對比下，具一明顯正相關關係；又自本試驗之數據顯示，每分蘖含稻細蟎若在 1,000 隻以下(齊穗期之密度)，不稔率增高不明顯，若超過 1,000 隻以上，不稔率便有急劇上升之勢，此一發現似可說明在田間稻細蟎密度甚低情況下，如以各種藥劑防治，不論其對稻細蟎防治效果之優劣，但最後如以不稔率比較，差異常不顯著。

據羅氏等試驗發現， Ethyl-parathion 對稻細蟎之主要天敵一臺灣捕植蟎（*Amblyseius taiwanicus*)之致死中間濃度（LC_{50}）在 10 ppm 以下，而 Dicofol 則在 500～1,000 ppm之間，Ethylparathion 對稻細蟎之天敵毒性極為强烈；且此藥劑對人畜毒性亦極高，害蟲對其又易生抗藥性；Gutierrez 在馬拉加西（Madagascar）發現稻細蟎發生猖獗，他認為是由於稻田用藥頻度太繁，而所施用之藥劑均對稻細蟎無效，反之對其天敵則毒性極高 [17]。吾人亦應顧慮此一觀點。因 Dicofol 無 Ethyl-parathion 之缺點，而其對稻細蟎之防治效果亦極優，故筆者認為宜以 Dicofol 防治稻細蟎之猖獗為害。

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Screening of chemicals for the control of rice tarsonemid mite, *Steneotarsonemus spinki*[1]

Kang Chen Lo, Chyi Chen Ho and Kuo Chin Lin[2]

Summary

The effects of parathion, dicofol, azomite, diazinon and MIPC in the control of the rice tarsonemid mite, *Steneotarsonemus spinki* (Acarina : Tarsonemidae), were compared in the greenhouse. The results of parathion and dicofol demonstrated that both chemicals were very effective in controlling the rice tarsonemid mites with the control rate at 99.9 to 97% and the sterility of rice at 7.3 to 7.7%. The results of other three pesticide treatments was rather poor, the mite control rates were ranged from 82.9 to 45.0% and the sterilities of rice were ranged from 13.5 to 39.8%. The check plots showed a thirty-four times increase in mite numbers from the start to the end of this experiment and the sterility of rice was 72.0%.

We prefer to recommend dicofol for the rice tarsonemid mite control because parathion has high mammalian toxicity and undesirable side effects on beneficial species and non-target organisms.

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The genera of Aphidiidae (Hymenoptera: Ichneumonoidea) in Taiwan[1]

Liang-yih Chou[2]

Abstract : A tentative key to 17 genera and subgenera of Aphidiidae of Taiwan is prepared in this paper. Three genera, *Toxares* Haliday, *Diaeretus* Foerster and *Lysiphlebus* Foerster ; and 2 species, *Toxares shigai* Takada and *Diaeretus leucopterus* (Haliday) is new to Taiwan. Diagnosis of these genera and subgenera, host-parasitoid and parasitoid-host lists of Taiwan are also presented.

The family Aphidiidae is a small group of the superfamily Ichneumonoidea. It is closely related to the subfamily Euphorinae of the Braconidae and, until recently, has been classified as a subfamily of the Braconidae. However, most workers of this group classify Aphidiidae as a distinct family, and I am much inclined to follow this arrangement. The Aphidiidae are the most important group of natural enemies of aphids. The fullgrown larvae of most genera spins a cocoon inside the empty skin of the victim whereas that of *Praon* and *Dyscritulus* make a peculiar tent like cocoon beneath the aphid skin. Moreover, both manners of pupations occurred in *Areopraon* (21). The aphidiid parasitoids of aphids are one of the group whose utilization in biological control has given significant results in many countries. The research on aphid parasitoids has also been included in the international programs.

More than 375 species of aphidiids belonging to 48 genera and subgenera have been known to occur in the world. The aphidiid fauna of Taiwan is poorly studied now, only 11 genera and 32 species of aphidiids were recorded (1,3,6,7,23,24). In this paper, 3 genera and 2 species are added to the aphidiid fauna of Taiwan. A number of other genera and species are presumed to be found here in the future. The key used in this paper is slightly modified from Stary (1970).

Tentative key to the genera and subgenera of Aphidiidae in Taiwan

1. Cubitus developed throughout, separating cubital cell I from discoidal cell (figs. 1, 2) ··················2
- Cubitus effaced frontally or entirely, cubital cell I and discoidal cell I confluent (figs. 3-13) ········4

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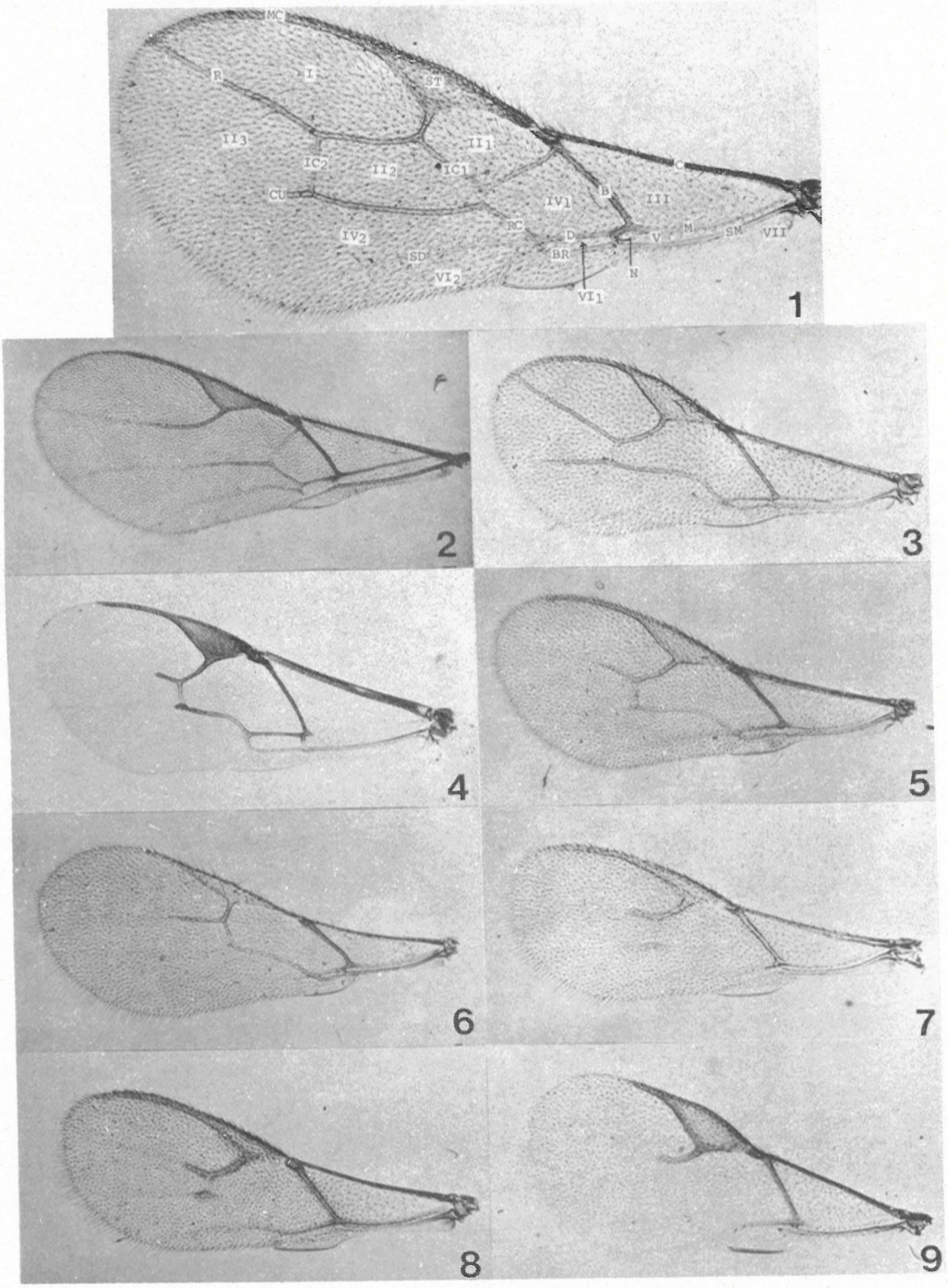
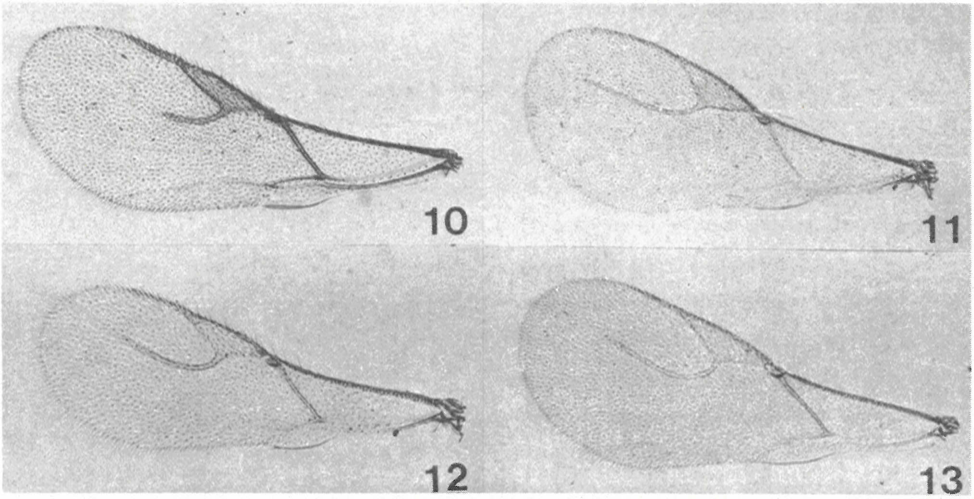
2. Both intercubiti developed (fig. 1) ···3
- Both intercubiti effaced (fig. 2). Propodeum smooth ; ovipositor sheath sparsely haired ·· *Praon* Haliday
3. Ovipositor sheath and ovipositor straight or slightly curved downwards ; antenna 10 or 11-segmented in both sexes ; abdomen lanceolate···································*Ephedrus* Haliday
 Ovipositor sheath curved downwards, rather broadened, deltoid and trifid at extremity ; ovipositor curved downwards ; antenna 15 to 20-segmented in female and 18 to 23-segmented in male ; abdomen rounded··*Toxares* Haliday
4. Cubital and discoidal cells confluent, distinctly completed by 2nd intercubitus along their external margin (2nd intercubitus sometimes nearly colourless but distinct) (figs. 3-8) ··················· 5
 Cubital and discoidal cells confluent, open, not completed by 2nd intercubitus along their external margin (figs. 9-13) ··11
5. Radial cell distinctly complete (fig. 3). Eye large ; antenna filiform ; notaulix effaced ; propodeum partially carinated ; abdomen lanceolate ; tergite I distinctly longer than wide at spiracles··· *Archaphidus* Stary & Schlinger
- Radial cell incomplete (figs. 4-8) ·· 6
6. Confluent cubital and discoidal cells distinctly separated on lower margin by fused recurrent vein and cubitus (figs. 4-6). ·· 7
 Confluent cubital and discoidal cells on the lower margin open the rest of cubitus visible only under the 2nd intercubitus (figs. 7, 8) ··10
7. Ovipositor sheath slightly curved upwards··· 8
- Ovipositor sheath curved downwards···*Monoctonus* Haliday
8. Carinae on propodeum forming large wide pentagonal areola······························*Pauesia* Quilis, 9
- Carinae on propodeum forming very narrow, small, central areola. ·······················*Aphidius* Nees
9. Ovipositor sheath wide, apex of the ovipositor lanceolate··············*Pauesia* (*Paraphidius*) Stary
- Ovipositor sheath slender, apex of the ovipositor acute··································*Pauesia* (s. str.)
10. Tergite I with more or less developed central tubercle only, without central carina or coarse rugosities···*Lysiphlebus* Foerster
- Tergite I with more or less distinct central carina, more or less rugose··*Lysiphlebia* Stary & Schlinger
11. Ovipositor sheath curved downwards, terminal abdominal sternite sometimes with 1-2 prongs······12
- Ovipositor sheath straight or slightly curved upwards, terminal abdominal sternite without posterior prongs ···16
12. Terminal abdominal sternite with 1-2 longer or shorter prongs. ·································13
- Terminal abdominal sternite without prongs··*Lipolexis* Foerster
13. Terminal abdominal sternite with 1 upward curved prong··················*Bioxys* Stary & Schlinger
- Terminal abdominal sternite with 2 upward curved to nearly straight prongs···*Trioxys* Haliday, 14
14. Tergite I with primary (=spiracular) and secondary tubercles (figs. 15, 16), the latter sometimes poorly visible being almost fused with primary tubercles···15
- Tergite I with primary tubercles only (fig. 14) ···*Trioxys* (s. str.)
15. Prongs of the last sternite beginning at the apex of sternite (fig. 18) ··*Trioxys* (*Binodoxys*) Mackauer
- Prongs of the last sternite beginning near the base of sternite (fig. 19) ··*Trioxys* (*Fissicaudus*) Stary & Schlinger

16. Notaulix entirely effaced ; propodeum with more or less distinct wide central areola··*Diaeretus* Foerster

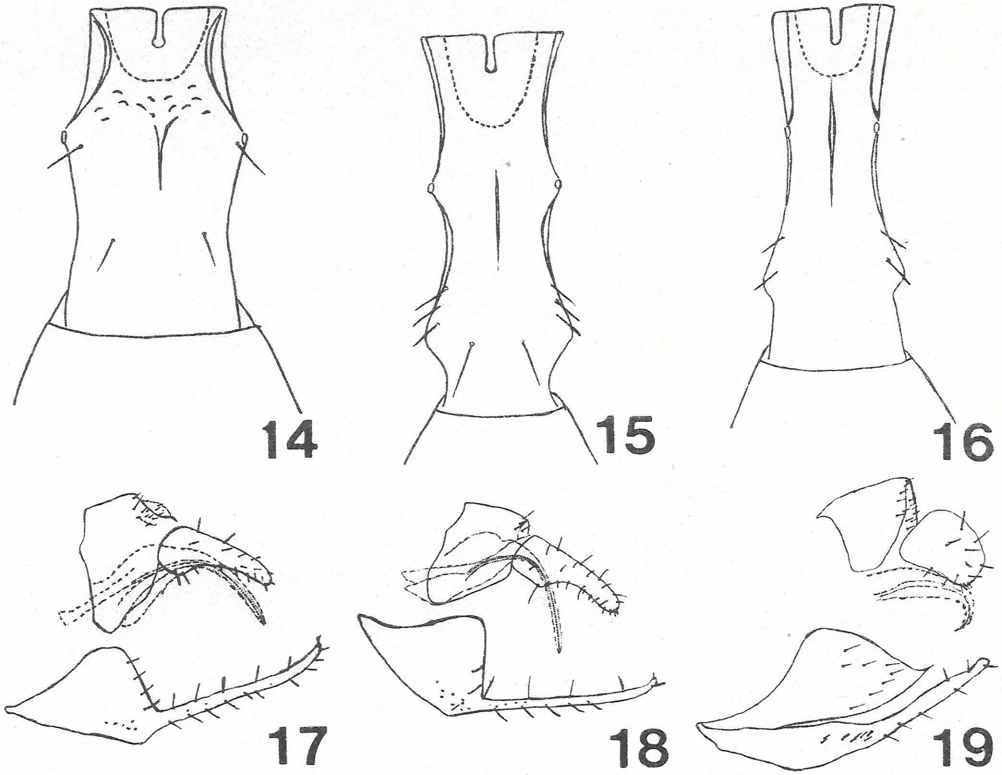
Notaulix distinct anteriorly ; propodeum with distinct small central areola·········*Diaeretiella* Stary



figs. 1-9, Fore wings : 1, *Ephedrus plagiator* (Veins : B, Basal ; C, Costa ; CU, Cubitus ; D, Discoideus ; IC, Intercubitus ; M, Medius ; MC, Metacarp ; N, Nervulus ; R, Radius ; RC, Recurrent ; SD, Subdiscoideus ; SM, Submedius ; ST, Stigma. Cells : I, Radial ; II, Cubital ; III, Medial ; IV, Discoidal ; V, Submedial ; VI, Brachial ; VII, Anal.) ; 2. *Praon orientale* ; 3, *Archaphidus greenideae* ; 4. *Pauesia unilachni* ; 5, *Aphidius gifuensis* ; 6, *Monoctonus woodwardiae* ; 7, *Lysiphlebia japonica* ; 8, *Lysiphlebus* sp. ; 9, *Diaeretus leucopterus*.



figs. 10–13. Fore wings : 10, *Diaeretiella rapae* ; 11, *Lipolexis gracilis* ; 12, *Trioxys auctus* ; 13, *Bioxys* sp.



figs. 14–16. Petiole of *Trioxys* : 14, *auctus* ; 15, *indicus* ; 16, *confucius*. 17–19, Female genitalia of *Trioxys* : 17, *auctus* ; 18, *indicus* ; 19, *confucius*.

Genus **Ephedrus** Haliday

Aphidius (*Ephedrus*) Haliday 1833 : 261, 485. Type species : *Bracon plagiator* Nees.
Elassus Wesmael 1835 : 85. Type species : *Elassus parcicornis* Wesmael.

Diagnosis : Head transverse. Antenna 10 or 11-segmented in both sexes. Notaulix at least partly distinct. Wing-venation as figured (fig. 1). Propodeum areolated, disc of areolae smooth, sometimes slightly rugose along carinae. Ovipositor sheath long and narrow, gradually and evenly narrowing towards apex, with scattered hairs.

Distribution : Holarctic, Ethiopian, Oriental and Australian regions.

Seven species, *E. lacertosus* (Haliday), *E. nacheri* Quilis, *E. niger* Gautier et al. , *E. orientalis* Stary & Schlinger, *E. persicae* Froggatt, *E. plagiator* (Nees) and *E. robustus* Liu have been known in Taiwan.

Genus **Toxares** Haliday

Aphidius (*Trionyx*) Haliday 1833 : 487. Type species : *Aphidius* (*Trionyx*) *deltiger* Haliday.
Toxares Haliday 1840 *in* Westwood 1840 : 65. Type species : *Aphidius* (*Trionyx*) *deltiger* Haliday.

Diagnosis : Head subquadrate. Antenna 15 to 20-segmented in female and 18 to 23-segmented in male. Notaulix distinct anteriorly. Propodeum completely areolated. Wing-venation is similar to *Ephedrus* Haliday. Ovipositor sheath curved downwards, rather broadened, deltoid and trifid at extremity.

Distribution : Palearctic and Oriental regions.

Toxares shigai Takada, the genus and species are new to Taiwan (Ilan : Jenche hot springs, 1♀, 31. XII. 1978 (K. C. Chou) ; Taichung : Sheng-kuang, 1850m, 1♂, 20. IX. 1968 (K. S. Lin)).

Genus **Praon** Haliday

Aphidius (*Praon*) Haliday 1833 : 483. Type species : *Bracon exoletus* Nees.
Bracon (*Achoristus*) Ratzeburg 1852 : 31. Type species : *Bracon* (*Achoristus*) *aphidiiformis* Ratzeburg.
Aphidaria Provancher 1886 : 151. Types pecies : *Aphidaria simulans* Provancher.

Diagnosis : Head subcubical. Antenna 14 to 23-segmented in female and 16 to 26-segmented in male. Notaulix distinct throughout. Propodeum smooth. Wing-venation as figured (fia. 2). Ovipositor sheath nearly straight to slightly curved upwards, slenderly triangular, pointed at apex, with sparse hairs.

Distribution : Holarctic and Oriental regions.

Two species, *P. dorsale* (Haliday) and *P. orientale* Stary & Schlinger have been known in Taiwan.

Genus **Pauesia** Quilis

Pauesia Quilis 1931 : 67. Type species : *Pauesia albuferensis* Quilis.

Diagnosis : Head transverse. Antenna 16 to 29-segmented in female and 19 to 32-seg-

mented in male. Notaulix more or less distinct. Wing-venation as figured (fig. 4). Propodeum with large wide pentagonal areola. Ovipositor sheath more or less curved upwards to nearly straight.

Distribution : Holarctic, Ethiopian and Oriental regions.

Pauesia Quilis consists of the 2 subgenera, *Paraphidius* Stary and *Pauesia* s. str. Both of them were recorded in Taiwan.

Subgenus **Paraphidius** Stary

Aphidius (*Paraphidius*) Stary 1958 : 56. Type species : *Aphidius californicus* Ashmead.

Diagnosis : Antenna 18 to 29-segmented in female and 20 to 32-segmented in male. Ovipositor sheath wide, apex of the ovipositor lanceolate.

Distribution : Holarctic, Ethiopian and Oriental regions.

Two species, *P. laticeps* (Gahan) and *P. salignae* (Watanabe) have been known in Taiwan.

Subgenus **Pauesia** s. str.

Pauesia (*Pauesia*) Stary 1976 : 111. Type species : *Pauesia albuferensis* Quilis.

Diagnosis : Antenna 16 to 23-segmented in female and 19 to 29-segmented in male. Ovipositor sheath slender, apex of the ovipositor acute.

Distribution : Holarctic and Oriental regions.

Only *P. unilachni* (Gahan) has been known in Taiwan.

Genus **Diaeretus** Foerster

Diaeretus Foerster 1862 : 249. Type species : *Aphidius leucopterus* Haliday.

Diagnosis : Head strongly transverse. Antenna 15 or 16-segmented in female and 16 to 18-segmented in male. Notaulix effaced. Wing-venation as figured (fig. 9). Propodeum with central carina and its bifurcation distinctly developed. Ovipositor sheath wide, comparatively short and slightly narrowed at apex, somewhat curved downwards.

Distribution : Palearctic and Oriental regions.

Only *D. leucopterus* (Haliday), has been known in the world. On this occasion I given Taiwan as a new locality of this species (Taipei Botanical Garden, 1♀, 19. I. 1978 (C. C. Tao), & Taoyuan : Chungli, 3♀, 9. III. 1977 (W. J. Wu), ex *Eulachnus thunbergii* on *Pinus*).

Genus **Archaphidus** Stary & Schlinger

Archaphidus Stary & Schlinger 1967 : 30. Type species : *Archaphidus greenideae* Stary & Schlinger.

Diagnosis : Head transverse. Antenna 17-segmented in female and 18-segmented in male. Notaulix effaced. Wing-venation as figured (fig. 3). Propodeum partly carinated. ovipositor sheath curved upwards.

Distribution : Oriental region.

This genus represented only by a single species, *A. greenideae* Stary & Schlinger in the world.

Genus **Aphidius** Nees

Incubus Schrank 1802 : 315. Type species : *Ichneumon aphidum* Linnaeus.

Aphidius Nees 1818 : 302. Type species : *Aphidius avenae* Haliday.

Theracmion Holmgren 1872 : 99. Type species : *Theracmion arcticus* Holmgren.

Aphidius (*Euaphidius*) Mackauer 1961 : 10. Type species : *Aphidius pterocommae* Ashmead.

Diagnosis : Head transverse. Antenna 12 to 21-segmented in female and 15 to 22-segmented in male. Notaulix distinct at the ascendent part of mesoscutum. Wing-venation as figured (fig. 5). Propodeum areolated, with narrow and small central areola. Ovipositor sheath comparatively short, slightly curved upwards, sparsely haired.

Distribution : Cosmopolitan.

Six species, *A. absinthii* Marshall, *A. amamioshimensis* Takada, *A. colemani* Viereck, *A. ervi* Haliday, *A. gifuensis* Ashmead and *A. salicis* Haliday have been known in Taiwan.

Genus **Diaeretiella** Stary

Diaeretiella Stary 1960 : 242. Type species : *Aphidius rapae* M'Intosh.

Diagnosis : Head transverse. Antenna 13 to 15-segmented in female and 15 to 18-segmented in male. Notaulix distinct anteriorly. Wing-venation as figured (fig. 10). Propodeum distinctly areolated. Ovipositor sheath straight or slightly curved upwards, sparsely haired.

Distribution : Cosmopolitan.

This genus represented only by a cosmopolitan species, *D. rapae* (M'Intosh) in the world.

Genus **Lysiphlebus** Foerster

Lysiphlebus Foerster 1862 : 248. Type species : *Aphidius* (=*Bracon*) *dissolutus* (Nees).

Aphidaria Provancher 1888 : 396. Type species : *Aphidaria basilaris* Provancher.

Diagnosis : Head transverse. Antenna 11 to 14-segmented in female and 14 to 17-segmented in male. Notaulix distinct at the ascendent part of mesoscutum. Wing-venation as figured (fig. 8). Propodeum entirely smooth or with 2 short divergent carinae at lower part. Tergite I widerly or prolongatedly triangular, smooth, with central and more or less prominent lateral-spiracular tubercles. Ovipositor sheath triangularly prolongated, slightly arcuate, slightly pointed to somewhat angular at apex.

Distribution : Almost cosmopolitan.

This genus is new to Taiwan.

Genus **Lysiphlebia** Stary & Schlinger

Lysiphlebia Stary & Schlinger 1967 ; 68. Type species ; *Lysiphlebus japonicus* Ashmead.

Diagnosis : Head transverse. Antenna 12 to 14-segmented in female and 14 to 17-segmented in male. Notaulix distinct at the ascendent part of mesoscutum. Wing-venation as figured (fig. 7). Propodeum entirely carinated, with medium sized (narrow) central areola. Tergite I slender or square, coarsely rugose, usually with longitudinal carina at the middle part. Ovipositor sheath very slightly curved upwards, gradually narrowing and rounded at apex .

Distribution : Palearctic and Oriental region.

Only *L. japonica* (Ashmead) has been known in Taiwan.

Genus **Monoctonus** Haliday

Aphidius (*Monoctonus*) Haliday 1833 : 261, 487. Type species : *Aphidius* (*Monoctonus*) *caricis* Haliday.

Aphidileo Rondani 1888 : 14. Type species : *Aphidius resolutus* Nees.

Diagnosis : Head subcubical. Antenna 13 to 16-segmented in female and 15 to 17-segmented in male. Notaulix distinct anteriorly. Wing-venation as figured (fig. 6). Propodeum with distinct central pentagonal areola or only with two divergent carinae in lower part. Ovipositor sheath curved downwards, plougshare-shaped.

Distribution : Holarctic and Oriental region.

Monoctonus Haliday consists of the 3 subgenera, *Monoctonus* s. str. , *Paramonoctonus* Stary and *Harkeria* Cameron. Only *M.* (*Monoctonus*) *woodwardiae* Stary & Schlinger has been known in Taiwan.

Genus **Lipolexis** Foerster

Lipolexis Foerster 1862 : 249. Type species : *Lipolexis gracilis* Foerster.

Gynocryptus Quilis 1931 : 27. Type species : *Gynocryptus pieltaini* Quilis.

Diagnosis : Head transverse to subquadrate. Antenna 12-segmented in female and 13-segmented in male. Notaulix distinct at the ascendent part of mesoscutum. Wing-venation as figured (fig. 11). Propodeum areolated. Ovipositor sheath curved downwards.

Distribution : Palearctic and Oriental regions.

Two species, *L. gracilis* Foerster and *L. scutellaris* Mackauer have been known in Taiwan.

Genus **Trioxys** Haliday

Aphidius (*Trioxys*) Haliday 1833 : 261. Type species : *Aphidius cirsii* Curtis.

Misaphidius Rondani 1877 : 185. Type species : *Misaphidus aphidiperda* Rondani.

Neuropenes Provancher 1886 : 151. Type species : *Neuropenes ovalis* Provancher.

Diagnosis : Head transverse. Antenna 10 to 12-segmented in female and 12 to 14-segmented in male. Notaulix distinct at the ascendent part of mesoscutum. Wing-venation as figured (fig. 12). Propodeum smooth or areolated. Ovipositor sheath curved downwards. Last sternite of female with a pair of simple prongs.

Distribution : Cosmopolitan.

Trioxys Haliday consists of the 5 subgenera, *Betuloxys* Mackauer, *Trioxys* s. str. ,

Pectoxys Mackauer ; *Binodoxys* Mackauer and *Fissicaudus* Stary & Schlinger, of which *Trioxys*, *Binodoxys* and *Fissicaudus* have been known in Taiwan.

Subgenus **Trioxys** s. str.

Trioxys (*Trioxys*) Mackauer 1959 : 149. Type species : *Aphidius cirsii* Curtis.

Diagnosis : Antenna 11 or 12-segmented in female and 12 to 14-segmented in male. Propodeum smooth or areolated. Tergite I with primary tubercles only (fig. 14). Prongs beginning at the apex of last sternite (fig. 17).

Distribution : Holarctic and Oriental regions.

Two species, *T. auctus* (Haliday) and *T. shivaphis* Takada have been known in Taiwan.

Subgenus **Binodoxys** Mackauer

Trioxys (*Binodoxys*) Mackauer 1960 : 141. Type species : *Aphidius* (*Trioxys*) *angelicae* Haliday.

Diagnosis : Antenna 10 or 11-segmented in female and 12 or 13-segmented in male. Propodeum more or less areolated. Tergite I with primary and secondary tubercles (fig. 15), the latter sometimes poorly visible being almost fused with primary tubercles. Prongs beginning at the apex of last sternite (fig. 18).

Distribution : Holarctic and Oriental regions.

Five species, *T. carinatus* Stary & Schlinger, *T. communis* Gahan, *T. indicus* Subba Rao & Sharma, *T. struma* Gahan and *T. toxopterae* Takada have been known in Taiwan.

Subgenus **Fissicaudus** Stary & Schlinger

Trioxys (*Fissicaudus*) Stary & Schlinger 1967 : 122. Type species : *Trioxys* (*Binodoxys*) *confucius* Mackauer.

Diagnosis : Antenna 11-segmented in female and 13-segmented in male. Propodeum areolated. Tergite I with primary and secondary tubercles (fig. 16) . Prongs beginning near the lateral base of last sternite (fig. 19).

Distribution : Palearctic and Oriental region.

Only *T. confucius* Mackauer has been known in Taiwan.

Genus **Bioxys** Stary & Schlinger

Bioxys Stary & Schlinger 1967 : 32. Type species : *Bioxys japonicus* Stary & Schlinger.

Diagnosis : Head transverse. Antenna 11-segmented in female and 13-segmented in male. Notaulix distinct at the ascendent part of mesoscutum. Wing-venation as figured (fig. 13). Propodeum areolated. Tergite I with primary tubercles. Ovipositor sheath curved downwards. Last sternite of female with one upwardly curved prong.

Distribution : Palearctic and Oriental regions.

Only an unidentified species of this genus has been known in Taiwan.

List of aphidiids and their hosts in Taiwan

Aphidius absinthii
- *Macrosiphoniella formosartemisiae*
- *M. yomenae*
- *M. yomogifoliae*

Aphidius amamioshimensis
- *Aulacorthum nipponicum*

Aphidius colemani
- *Hyalopterus pruni*

Aphidius ervi
- *Acyrthosiphon pisum*
- *Macrosiphum* sp.

Aphidius gifuensis
- *Capitophorus* sp.
- *Lipaphis erysimi*
- *Myzus persicae*
- *Myzus* sp.
- *Sitobion ibarae*

Aphidius salicis
- *Cavariella araliae*
- *C. salicicola*

Aphidius spp.
- *Sitobion ibarae*
- *Titanosiphon neoartemisiae*

Archaphidus greenideae
- *Greenidea ficicola*
- *G. formosana*

Bioxys sp.
- *Myzocallis* sp.

Diaeretiella rapae
- *Brevicoryne brassicae*
- *Greenidea ficicola*
- *Lipaphis erysimi*
- *Myzus persicae*

Diaeretus leucopterus
- *Eulachnus thunbergii*

Ephedrus lacertosus
- *Macromyzus woodwardi*

Ephedrus nacheri
- Unknown

Ephedrus niger
- *Uroleucon formosanum*
- *Uroleucon* sp.

Ephedrus orientalis
- *Hyalopterus pruni*
- *Hyperomyzus carduellini*

Ephedrus persicae
- *Aphis citricola*
- *A. gossypii*
- *Brevicoryne brassicae*
- *Hyalopterus pruni*
- *Lipaphis erysimi*
- *Myzus persicae*
- *Tinocallis ulmiparvifoliae*
- *T. viridis*
- *Trichosiphoniella momoni*

Ephedurs plagiator
- *Acyrthosiphon pisum*
- *Aphis citricola*
- *A. gossypii*
- *A. rumicis*
- *Brachysiphoniella monta*
- *Cavariella araliae*
- *Hyalopterus pruni*
- *Hyperomyzus lactucae*
- *Lipaphis erysimi*
- *Macromyzus woodwardic*
- *Macrosiphum* sp.
- *Myzus persicae*
- *Rhopalosiphum maidis*
- *Sinomegoura citricola*
- *Sitobion ibarae*
- *Toxoptera aurantii*

T. odinae

Uroleucon formosanum

U. gobonis

Ephedrus robustus

Aphis citricola

Melanaphis sacchari

Rhopalosiphum maidis

Ephedrus sp.

Cavariella salicicola

Lipolexis gracilis

Aphis citricola

A. craccivora

A. glycines

A. gossypii

A. nerri

Melanaphis sacchari

Myzus persicae

Rhopalosiphum maidis

Semiaphis heraclei

Toxoptera aurantii

T. citricidus

Lipolexis scutellaris

Aphis citricola

A. craccivora

Cavariella araliae

Pentalonia nigronervosa

Semiaphis heraclei

Toxoptera aurantii

T. citricidus

Lysiphlebia japonica

Aphis citricola

A. craccivora

A. gossypii

A. pomi

A. rumicis

Melanaphis sacchari

Rhopalosiphum maidis

Titanosiphon neoartemisiae

Toxoptera aurantii

T. odinae

Monoctonus woodwardiae

Macromyzus woodwardiae

Pauesia laticeps

Cinara sp.

Pauesia salignae

Tuberolachnus salignus

Pauesia unilachni

Cinara formosana

Schizolachnus sp.

Unilachnus sp.

Praon dorsale

Indomegoura indica

Uroleucon formosanum

U. gobonis

Praon orientale

Hyperomyzus lactucae

Praon spp.

Myzus hemerocallidis

Uroleucon formosanum

Toxares shigai

Unknown

Trioxys (Binodoxys) carinatus

Microlophium rubiformosanum

Trioxys (Binodoxys) citri (N. nudum) [24]

Aphis citricola

Trioxys (Binodoxys) communis

Aphis glycines

A. gossypii

Rhopalosiphum sp.

Trioxys (Binodoxys) formosanus (N. nudum) [24]

Acyrthosiphon pisum

Trioxys (Binodoxys) indicus

Aphis gossypii

Trioxys (Binodoxys) smilicis (N. nudum) [7]

Aphis smilacifoliae

Trioxys (Binodoxys) struma

Sinomegoura citricola

Toxoptera aurantii

Trioxys (Binodoxys) toxoptera

Toxoptera aurantii

Trioxys (Binodoxys) sp.

Aphis citricola

Trioxys (Fissicaudus) confucius

Greenidea ficicola

G. formosana

Trioxys (T.) auctus

Rhopalosiphum nympheae

R. padi

Trioxys (T.) bambusa (N. nudum)(7)

Cranaphis formosana

Trioxys (T.) shivaphis

Shivaphis celti

Shivaphis sp.

Tinocallis ulmiparvifoliae

Trioxys (T.) sp.

Chucallis bambusicola

Trioxys spp.

Acyrthosiphon pisum

Aphis citricola

List of aphids and their aphidiid parasitoids in Taiwan

Acyrthosiphon pisum

Aphidius ervi

Ephedrus plagiator

Trioxys (Binodoxys) formosanus

Trioxys sp.

Aphis citricola

Ephedrus persicae

E. plagiator

E. robustus

Lipolexis gracilis

L. scutellaris

Lysiphlebia japonica

Trioxys (Binodoxys) citri

Trioxys sp.

Aphis craccivora

Lipolexis gracilis

L. scutellaris

Lysiphlebia japonica

Aphis glycines

Lipolexis gracilis

Trioxys (Binodoxys) communis

Aphis gossypii

Ephedrus persicae

E. plagiator

Lipolexis gracilis

Lysiphlebia japonica

Trioxys (Binodoxys) communis

Trioxys (Binodoxys) indicus

Aphis nerri

Lipolexis gracilis

Aphis pomi

Lysiphlebia japonica

Aphis rumicis

Ephedrus plagiator

Lysiphlebia japonica

Aphis smilacifoliae

Trioxys (Binodoxys) smilicis

Aulacorthum nipponicum

Aphidius amamioshimensis

Brachysiphoniella montana

Ephedrus plagiator

Brevicoryne brassicae

Diaeretiella rapae

Ephedrus persicae

Capitophorus sp.

Aphidius gifuensis

Cavariella araliae

Aphidius salicis

Ephedrus plagiator

Lipolexis scutellaris

Cavariella salicicola

Aphidius salicis

Ephedrus sp.

Chucallis bambusicola

Trioxys (T.) sp.

Cinara formosana

Pauesia unilachni

Cinara sp.

Pauesia laticeps

Cranaphis formosana

Trioxys (T.) bambusa

Eulachnus thunbergii

Diaeretus leucopterus

Greenidea ficicola

Archaphidius greenideae

Diaeretiella rapae

Trioxys (Fissicaudus) confucius

Greenideae formosana

Archaphidius greenideae

Trioxys (Fissicaudus) confucius

Hyalopterus pruni

Aphidius colemani

Ephedrus plagiator

E. orientalis

E. persicae

Hyperomyzus carduellinus

Ephedrus orientalis

Hyperomyzus lactucae

Ephedrus plagiator

Praon orientale

Indomegoura indica

Praon dorsale

Lipaphis erysimi

Aphidius gifuensis

Diaeretiella rapae

Ephedrus persicae

E. plagiator

Macromyzus woodwardiae

Ephedrus plagiator

E. lacertosus

Monoctonus (M.) woodwardiae

Macrosiphoniella formosartemisiae

Aphidius absinthii

Macrosiphoniella yomenae

Aphidius absinthii

Macrosiphoniella yomogifoliae

Aphidius absinthii

Macrosiphum sp.

Aphidius ervi

Ephedrus plagiator

Melanaphis sacchari

Lipolexis gracilis

Lysiphlebia japonica

Ephedrus robustus

Microlophium rubiformosanum

Trioxys (Binodoxys) carinatus

Myzocallis sp.

Bioxys sp.

Myzus hemerocallidis

Praon sp.

Myzus persicae

Aphidius gifuensis

Diaeretiella rapae

Ephedrus persicae

E. plagiator

Lipolexis gracilis

Myzus sp.

Aphidius gifuensis

Pentalonia nigronervosa

Lipolexis scutellaris

Rhopalosiphum maidis

Ephedrus plagiator

E. robustus

Lipolexis gracilis

Lysiphlebia japonica

Rhopalosiphum nympheae

Trioxys (T.) auctus

Rhopalosiphum padi

Trioxys (T.) auctus

Rhopalosiphum sp.

Trioxys (Binodoxys) communis

Schizolachnus sp.

Pauesia unilachni

Semiaphis heraclei

Lipolexis gracilis

L. scutellaris

Shivaphis celti

Trioxys (T.) shivaphis

Shivaphis sp.

Trioxys (T.) shivaphis

Sinomegoura citricola

Ephedrus plagiator

Trioxys (Binodoxys) struma

Sitobion ibarae

Aphidius gifuensis

Aphidius sp.

Ephedrus plagiator

Tinocallis viridis

Ephedrus persicae

Tinocallis ulmiparvifoliae

Ephedrus persicae

Trioxys (T.) shivaphis

Titanonosiphon neoartemisia

Aphidius sp.

Lysiphlebia japonica

Toxoptera aurantii

Ephedrus plagiator

Lipolexis gracilis

L. scutellaris

Lysiphlebia japonica

Trioxys (Binodoxys) struma

T. (Binodoxys) toxopterae

Toxoptera citricidus

Lipolexis gracilis

L. scutellaris

Toxoptera odinae

Ephedrus plagiator

Lysiphlebia japonica

Tuberocephalus momonis

Ephedrus persicae

Tuberolachnus salignus

Pauesia salignae

Unilachnus sp.

Pauesia unilachni

Uroleucon formosanum

Ephedrus plagiator

E. niger

Praon dorsale

Praon sp.

Uroleucon gobonis

Ephedrus plagiator

Praon dorsale

Uroleucon sp.

Ephedrus niger

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臺灣蚜繭蜂科屬之整理[1]

周樑鎰[2]

中文摘要

蚜繭蜂 (aphidiid) 係蚜蟲之重要寄生性天敵。該蜂之研究曾在國際間合作進行。全世界已記錄之蚜繭蜂有 39 屬，約 375 種，臺灣已記錄者僅 11 屬 32 種，寄生於 60 餘種之蚜蟲，而臺灣蚜蟲已記錄者達 269 種，可知臺灣蚜繭蜂仍有待加强詳細採集與研究。

筆者檢查本所歷年採集之蚜繭蜂標本約 6,200 隻，得 14 屬， 3 亞屬。本文將臺灣產之蚜繭蜂屬與亞屬編成檢索表，並附各屬之鑑別特徵，蚜繭蜂與寄主相互之對照表。其中 *Toxares* Haliday, *Diaeretus* Foerster 及 *Lysiphlebus* Foerster 等 3 屬爲臺灣新記錄。又 *Toxares shigai* Takada 與 *Diaeretus leucopterus* (Haliday) 爲臺灣新記錄種。

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Effects of inoculum concentrations on the resistance of peanuts to *Puccinia arachidis* Speg.[1]

Y. S. Lin[2]

Abstract: Four hundred and sixty-one accesions of peanuts were screened for resistance to peanut rust. Three accessions, P. I. 314817, P. I. 259747 and P. I. 315608, showed slow rusting under natural environments in Taiwan. When these accessions were screened in a rust nursery with an inoculum density higher than that in the natural field, the P. I. 314817 and P. I. 259747 became susceptible while P. I. 315608 remained resistant. Heavy infection occurred on all three accessions when they were inoculated with a spore suspension (200 mg of uredospores/plant) plus a wetting agent (Tween 80) in growth chamber. In another inoculation tests, each of the three accessions at 90 days old was inoculated with inoculum densities ranged from 2 to 200 mg of uredospores/plant in greenhouse. The results revealed that each accession had produced different amount of spores and degree of infection. Density of inoculum plays an important role in the infection and symptom expression. No different physiological races could be identified based on their reaction types on P. I. 314817, P. I. 259747, P. I. 315608 and TN-4 for the fourteen isolates of *P. arachidis* from Taiwan.

Peanut rust caused by *Puccinia arachidis* Speg. was first reported in Taiwan by Kao and Wu in 1970. It now occurs widely all over the island. When peanut plants are heavily infected, the leaves turn yellow and defoliated, seeds are smaller, and the yield, then, is reduced to about 50% (Huang and Chen, 1979). No commercial variety of peanuts in Taiwan is resistant to this disease. Therefore, searching for sources of resistance is extremely important in breeding program.

Three peanut genotypes, P. I. 259747 (Tarapoto). P. I. 314817 (DHT 200) and P. I. 315608 (Israel Line 136) were reported resistant to the rust in most peanut growing areas in the world (Bromfield, 1971; Hammons, 1977; Subrahmanyam, *et al*, 1980). However, the resistance of these genotypes is still controversial. McVey (1965) reported that peanut

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accessions exposed to natural rust infection in Puerto Rico, only P. I. 259747 had good resistance. However, rust symptoms were observed on seedlings of this accession when inoculated with a spore suspension and incubated in a saturated atmosphere for 16-24 hr in greenhouse. Bromfield and Cevario (1970) made inoculation in a dew chamber or plastic tent and suggested that in addition to P. I. 259747, two more accessions, P. I. 314817 and P. I. 315608, were physiologically resistant to rust isolates obtained from Texas and Puerto Rico. They also pointed out that the number of pustules developing on these accessions was consistantly less than that on the susceptible variety 'Starr' in a given inoculation test. The two rust isolates could not be separated into two physiological races on the basis of reaction types on the host accessions. Cook (1972) reported that P. I. 314817 and P. I. 259747 were resistant, but P. I. 315608 was highly susceptible to rust in Jamaica. He also indicated that the resistance of P. I. 259747 increased as the plant aged. This was confirmed by Subrahmanyam, *et al* in 1980. Romero (reviewed in Hammons, 1977) found that among the genotypes tested in Honduras, P. I. 259747 showed resistance, but P. I. 314817 and P. I. 315608 were susceptible.

The reasonable explainations for the above controversy are: (1) the physiological races of peanut rust fungus exist in the world; (2) the resistant accessions are not genetically uniform; or (3) the accessions may possess horizontal resistance to this fungus with the amount of resistance expressed being dependent on the environmental conditions. This study was conducted to determine whether these accessions are resistant to peanut rust in Taiwan, the possible use of them in breeding program and to evaluate whether one or more of the three explainations offered above are ture.

Materlals and Methods

Field screenings.-Peanut seeds of P. I. 314817, P. I. 259747 and P. I. 315608 were supplied by Dr. G. A. White in Maryland, U. S. A. and another 458 accessions were obtained from Taiwan Agricultural Research Institute (TARI) germplasm collection. All 461 accessions were screened by natural infection in the field at TARI in 1979. A simple spore trap equipped with four slides was set up 30-cm above the canopy in the center of the plots. The slides were coated with gel and changed daily. The number of uredospores per 3.24 cm^2 was counted under microscope. The disease readings were taken at 7 to 10-day intervals throughout the crop seasons. The degree of infection was rated by an "intensity grade scale" from R_0 to R_4, based on the percentage of leaf areas covered with pustules. R_0 signifies no pustules on leaves, R_1 less than 25%, R_2 from 26 to 50%, R_3 from 51 to 75%, and R_4 more than 75% of leaf areas covered with pustules. Disease index 1 is given to R_1, 2 to R_2, 3 to R_3, and 4 to R_4. All leaves on the main stem of each plant were sellected to record the disease intensity and calculated by the followi ng formula:

$$\text{Disease intensity} = \frac{NR_1 \times 1 + NR_2 \times 2 + NR_3 \times 3 + NR_4 \times 4}{(NR_0 + NR_1 + NR_2 + NR_3 + NR_4) \times 4} \times 100\%$$

N = Number of leaves recorded for each scale

The final score of disease intensity for each accession was obtained from the average

of 10 plants.

Rust nursery screenings.-A rust nursery was set up at TARI in 1979 by seeding many rows of the highly susceptible variety TN-4 every 20 to 30 days in a 0.3 ha field from Feburary to October. Forty pots of peanut plants infected with rust in the greenhouse were randomly distributed in the nursery as source of incoulum. Therefore, after the pathogen spreaded, the nursery could provide inoculum from May to December. The test accessions were planted, 50 cm between rows and 15 cm between plants within rows, in the nursery on May 8, 1979.

Greenhouse tests.-Fourteen isolates of *P. arachidis* collected from different peanut growing areas in Taiwan were used. Plants grown in pots were inoculated at 30, 60, or 90 days after seeding by spraying them as evenly as possible with uredospore suspension (0.1g/100ml) containing 0.1% of wetting agent (Tween 80). The inoculated plants were incubated in a transparent plastic tent for high humidity for 24 hr and then moved to a greenhouse bench at 25-30 C. The disease readings were taken 18 days after inoculation. Plants of 90 days old also were inoculated, 20 ml per plnat, with spore suspensions at 0.01, 0.05, 0.1, 0.5, or 1.0g/100ml. The amount of uredospores lodged on plants were approximately 2, 10, 20, 100, or 200 mg, respectively.

Estimates of uredospore production.-Ten fresh pustules formed on leaves after inoculation were cut at random 6 days after pustule formation, and then, every 3 days thereafter until the pustules were too old to produce spores. After every cutting, the spores in the remainning pustules on the leaves were removed entirely to permit new growth of uredospores and to prevent from the secondary infection. Each pustule on excised leaf were put on a slide with a drop of sterile water containing 0.1% wetting agent (Tween 80), and aggitated by a glass rod to free the uredospores from the pustule. The spores were counted under microscope by using a hemacytometer.

Results

Field screenings.-Peanut rust was severe at late growing season of the crop in 1979. Among the 461 accessions tested, only P. I. 314817, and P. I. 259747 showed less infection (fig. 1), and only P. I. 315608 showed no pustules o n leaves while accession TN-4 was highly susceptible and then was chosen as a susceptible check. Rust symptom were observed 60 days after seeding and came to the log phase around 70 days. Two peaks of uredospore concentrations in the field were observed in July and December (fig. 2). The peaks appearance coincided with the later stages of the two peanut crops (spring and autumn crops) a year in Taiwan.

Rust nursery screenings.-Uredospores in the air 30 cm above the canopy in the rust nursery from May to December in 1979 were successfully maintained at 200 to 700 uredospores/3.24 cm^2/day (fig. 3). Accessions P. I. 314817 , P. I. 259747 and P. I. 315608 were tested in the rust nursery. The first two accessions showed different reactions among plants with most plants fully susceptible but few resistant or moderately resistant (fig. 4). The disease started 29 days after seeding and the disease progress curve of susceptible type came to the log phase around 70 days after seeding. The third

accession (P. I. 315608) again was immune or nearly so.

Greenhouse tests.-Peanuts of P. I. 314817, P. I. 259747 and TN-4 were susceptible, in terms of number of pustule , when inoculated with 20 mg uredospores/plant, regardless of plants ages (30, 60 or 90 days old), in the greenhouse. However, P. I. 314817 and P. I. 259747 had fewer, smaller pustules and produced less spores compared with TN-4 (fig. 5), and P. I. 315608 showed immune reaction at this inoculum density. With regard to the reactions of the four accessions to fourteen rust isolates collected from different peanut growing areas in Taiwan, no differential reactions were observed. The results of further tests indicated that accessions showed different degree of infection with different inoculum concentrations (fig. 6). Plants of TN-4 were very susceptible to rust fungus even at 2 mg of uredospores applied per plant, the lowest inoculum density tested(fig. 6). In contrast, plants of P. I. 259747 and P. I. 314817 showed complete susceptibility to rust only at the highest inoculum density (200mg uredospores per plant) and showed progressively less disease with each increment redution of inoculum density down to 2 mg uredospores per plant which resulted no disease (fig. 6). Plants of P. I. 315608 only showed some rust when 100 mg and 200 mg of uredospore inoculum was applied per plant.

Discussion

Accessions P. I. 314817 and P. I. 259747 expressed a slow rusting reaction and P. I. 315608 showed highly resistant or near immune to *P. arachidis* under natural environments in Taiwan. In rust nursery, where the inoculum density was higher than that in the natural field, accessions P. I. 314817 and P. I. 259747 became susceptible but accession P. I. 315608 remained highly resistant or near immune. In greenhouse tests with increasing amounts of inoculum, P. I. 314817 and P. I. 259747 showed increasingly more rust severity as the inoculum density was increased. P. I. 315608 was essentially immune in the greenhouse tests except when plants were inoculated with very high spore concentration (200 mg of uredospores per plant) plus a wetting agent (Tween 80) which produced heavy infection on other accessions as well. The accessions P. I. 314817 and P. I. 259747 showed a mixture of resistance may indicate that those two accession are not genetically uniform.

Van der Plank (1968) visualized horizontal resistance as a type that slows an epidemic after a disease has started. The resistance of P. I. 314817, P. I. 259747, and P. I. 315608 may be considered as horizontal, with P. I. 315608 having the highest form of resistance. The resistance of all three accessions could be overcome by heavy load of inoculum with the greatest load required to overcome the resistance of P. I. 315608 (fig. 6), Inoculum density plays an important role in the degree of infection and symptom expression.

No matter how soon or how late the disease started in the disease nursery (fig. 4) or under natural conditions in the field (fig. 2), the disease progress curves came to the log phase around 70 days after seeding. This indicates that the crop canopy and inoculum density at that time created a favorable enviroment for the disease epidemic.

No different physiological races could be identified based on the reaction types of

the fourteen local isolates of *P. arachidis* in Taiwan on the accessions P. I. 314817, P. I. 259747, P. I. 315608 and TN-4. These four accessions showed a similar levels of resistance to all isolates. The results were in agreement with those of Bromfield and Cevarios' (1970) who used two isolates from Texas and Puerto Rico. In our studies, P. I. 315608 showed a much higher levels of resistance than reported by McVey (1965), Cook (1972) and Romero (reviewed in Hammons, 1977), suggesting that either these workers may used a very high inoculum density in their experiments or that they may have a different physiological race.

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接種源濃度影響落花生對銹病菌之抵抗性[1]

林 益 昇[2]

摘 要

本研究篩選461個花生品系對銹病菌之抵抗性，僅 P.I. 314817, P.I. 259747, 及 P.I. 315608 三個品系在天然環境下表現緩銹現象（slow rusting），當這三個品系在擁有較天然環境更高量接種源之銹病圃篩選時 P.I. 314817 及 P.I. 259747 則變爲罹病反應，而 P.I. 315608 仍是抗病反應。又有溫室中以胞子懸浮液加上展著劑（Tween 80）進行接種（200 mg胞子量／植株），則以上三個品系皆爲罹病反應。另外在溫室中以不同濃度(2～200 mg胞子量／植株)之胞子懸浮液噴到 90 天株齡的植株上時各品系皆表現不同程度之感染，而且夏胞子堆之產量亦有相當差距。可見銹病菌接種源濃度對各花生品系在感染之數量與病徵之表現扮演着重要角色。又從臺灣各花生栽培區收集的十四個銹病菌菌株，接種在 P.I. 314817, P.I. 259747, P.I. 315608 及 TN-4 四個鑑別品種上，並不能從其病徵之表現鑑別各菌株間有生理小種之分化現象。

1. 臺灣省農業試驗所 研究報告 第 957 號。

2. 本所研究員兼植物病理系系主任。臺灣省 臺中縣 霧峰鄉。

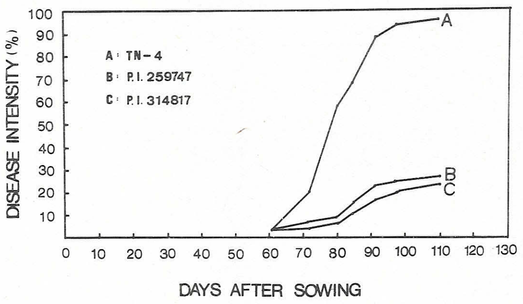

Fig. 1. Development of peanut rust on accessions TN-4, P. I. 314817, and P. I. 259747 under natural conditions in a field

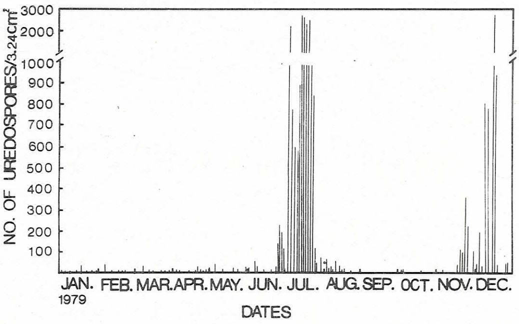

Fig. 2. Number of uredospores of *Puccinia arachidis* in the air 30 cm above a peanut field.

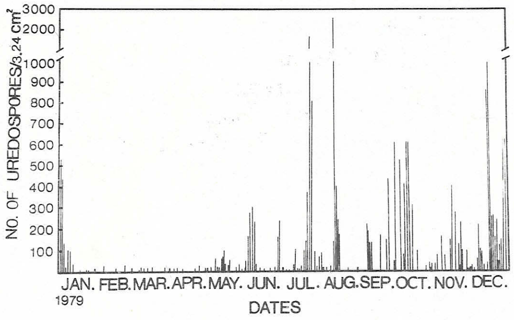

Fig. 3. Number of uredospores of *Puccinia arachidis* in the air 30 cm above a rust nursery, where inoculum was generated by continual planting of susceptible plants.

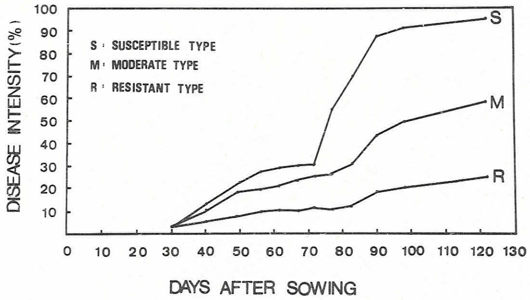

Fig. 4. Three types of peanut rust development among plants of accession P. I. 314817, and P. I. 259747 tested in rust nursery.

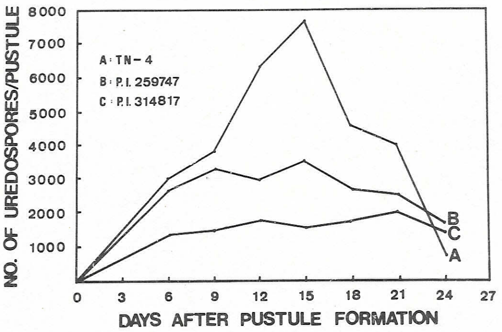

Fig. 5. Number of uredospores per pustule of *Puccinia arachidis* on accessions TN-4, P. I. 314817, and P. I. 259747.

Fig. 6. Reactions of four accessions of peanuts to *Puccinia arachidis* when inoculated with different inoculum concentrations in greenhouse. Identify the treatments on each accession from left to right: (Top row) 200, 100, 20, (Bottom row) 10, and 2 mg of uredospores per plant.

中華農業研究 (Jour. agric. Res. China) 30(3)：332～339 (1981)

洋菇腫柄病菌厚膜孢子之發芽及對本病發生之影響[1]

廖英明[2]

摘要：以不同處理方式來促進洋菇腫柄病菌(*Mycogone perniciosa* Magn.)厚膜孢子發芽，結果顯示以化學藥物處理，溫度處理及酸鹼處理均無法促使其在人工培養基中發芽。但若置於充滿洋菇菌絲代謝所產生之揮發性氣體之空間，則於 PDA 培養基上厚膜孢子在 16°～28°C 均可發芽，而 24°C 爲最適合發芽之溫度，3個月齡期之厚膜孢子爲最適合發芽之時期。厚膜孢子在培養 24 小時內很少發芽，且 12°C 以下及 32°C 以上均不發芽，發芽率在 1～14 %之間；厚膜孢子發芽管由下方之 Cell 中伸出，可有1支或2支，而後迅速分支或長出一段時間後再分支，約在培養 96 小時後，厚膜孢子之內含物全部脫離而轉移至發芽管，剩下一空殼。若將厚膜孢子接種於覆土中，則在第 20 天即可產生具有病徵型之洋菇子實體，且有二種病徵型存在。

洋菇腫柄病爲洋菇栽培中重要病害之一，發生嚴重時幾無收成，影響農民收益至鉅。目前對該病之防治僅能以藥劑來加以抑制，但效果並不理想。近期中，國外有關該病之防治方式，許多學者均有不同之結果 (6,11,12,13,18,19,21,23)。國內對該病之防治報告，有杜氏 (1,2) 認爲 125 ppm 之 Benlate 在 3.3m² 之菇床使用 1,000cc 時有良好的治療及預防效果，及洪氏 (3) 指出大生 M-22 之防治效果良好且無藥害發生。惟最近徐氏 (4) 之報告指出本省目前腫柄病發生極爲嚴重，藥劑已無法有效控制，而懷疑係本病菌已產生抗藥性。因此在對該病整個生態方面必須再加以重新瞭解，尤其是在該病之殘存及傳佈上更值得注意。該病之感染源主要來自覆土 (6,10)，而厚膜孢子可能爲其殘存方式。因此厚膜孢子之存在已決定了整個病害發生程度，而厚膜孢子如何進行發芽也成爲整個病害發生的重點。本病菌 *Mycogone perniciosa* 爲不完全菌，其有性世代可能爲 *Histoplasma capsulatum* (5,7) 後者爲一種動物寄生菌，可引起 Histoplasmosis 病。而 *M. perniciosa* 可產生二種型式之孢子，一種爲透明無色之 phialospore 另一種即爲厚壁之 aleuriospore 或 chlamydospore (7)。殘存時以厚膜孢子狀態存在於覆土中，堆肥或其他器具上，主要由水傳播，少部份由風及其他方式傳播，待於菇床栽培時則發芽而後擴展。導致整個洋菇子實體罹病。過去對該菌厚膜孢子之發芽均未見報告，而其發芽過程也未明瞭；而一般促進孢子發芽的方式有許多種類，Weber 氏等 (22) 在 "The fungal spore" 一書中提到的有：如以 Tween 20 處理可促進 *Colletotrichum trifollii* 孢子發芽；furans 及 thiophenes, pyrrole 等可促促進 *Neurospora* spp. 之 ascospore 發芽；另外 *Coprinus radiatus* 之孢子需要 44～46°C 4 小時之熱處理及 furfural 之處理才達到最高的發芽率；而以 isovalerate 及 isoamyl alcohol 處理 *Agaricus bisporus* 亦可促進其孢子之發芽，另外還有許多處理方式，不外化學及物理之刺激方式。本研究即在探討厚膜孢子發芽的過程及外在因素對厚膜孢子發芽之影響，以作爲日後研擬該病防治方法之參考。

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1. 臺灣省農業試驗所 研究報告 第 1007 號。本試驗承吳正球先生及廖莉莉小姐之協助，謹此申謝。

2. 本所植物病理系助理研究員。臺灣省 臺中縣 霧峰鄉。

材料及方法

一、病菌之來源：將採自名間鄉菇床之洋菇罹病子實體，切取病組織移殖於馬鈴薯洋菜培養基中，於 24°C 下培養。待其長出腫柄病菌之菌絲後，挑取菌落邊緣部份之菌絲塊，保存於試管斜面內，經過不同時間後分別挑取厚膜孢子作爲發芽試驗用。

二、厚膜孢子發芽促進試驗：由培養基斜面中刮取厚膜孢子後置於無菌水中，在 45°C 下處理10分鐘，將殘留之菌絲片斷去除。

1.化學藥物處理：以吡咯啶甲酸 (proline 5×10^{-3}M) 及甘醇 (ethyl glycol)，蔗糖 (sucrose)，、澥蘆糖 (trehalose) ，木糖 (xylose) 乙醇 (ethanol) ，甲醇 (methanol) ，氫氧化鈉 (NaOH 1N) ，鹽酸 (Hcl 0.1N) ，丙酮 (acetone) 、醋酸 (acetic acid) 、異戊酸 (isovaleric acid) 及異戊醇 (isoamyl alcohol) ，乙醚 (ethyl ether) ，苯 (benzene) ，正乙烷 (hexane) 等各 0.1M 加於 PDA 養培基中，再移入不同齡期 (6 、5 、4 、3 、2 、1 個月齡) 之厚膜孢子懸浮液，而後置於 24°C 之定溫箱中，觀察其發芽情形。

2.溫湯處理：將厚膜孢子懸浮液在各種不同溫度下作不同時間之處理，即在恆溫槽中於 70°C 下處理5分鐘，60°C 下處理 10 分鐘，50°C 下處理15分鐘，40°C 下處理 30 分鐘，並依照前項之方法將厚膜孢子懸浮液倒於 PDA 培養基平板中，置於 24°C 下觀察其發芽情形。

3.酸鹼處理：將 PDA 培養基以 0.1N Hcl 及 1N NaOH 調整其 pH 值爲 3.0、3.5、4.0、4、5、5.0、5.5、6.0、6.5、7.0、7.5、8.0、8.5 及 9.0 等不同酸鹼度，此種酸鹼度爲未經殺菌前之值，殺菌後之變化爲降低 pH 值0.2~0.3 ，而後將不同齡期之厚膜孢子懸浮液加於 PDA 平板上，置於 24°C 下，在 24~96 小時內觀察其厚膜孢子之發芽情形。

4.不同培養基之處理：將不同齡期之厚膜孢子加於下列培養中，置於 24°C 下培養，並觀察厚膜孢子之發芽情形，各培養基之配方如下：potato dextrose agar (potato 200g；dextrose 20g；agar 20g；distilled water 1 litre), compost agar (dry compost 25g；agar 20g；distilled water 1 litre), nutrient agar (nutrient broth pH7.2 1 litre ； agar 15g), GMY medium (glucose 10g；malt extract 10g；yeast extract 4g；distilled water 1 litre), soil extract agar (agar 15g；glucose 1.0g, K_2HPO_4 0.5g；soil extract 100ml；distilled water 900ml), potato sucrose agar (potato 200g；sucrose 20g；agar 20g；distilled water 1 litre)。

三、洋菇代謝氣體對厚膜孢子發芽之影響：以不同齡期之厚膜孢子塗抹於上置 water agar 或 PDA 之載玻片上，而後置於經消毒之半密閉玻璃盒中 (圖1) ，外罩以塑膠袋，並以橡皮管和菌種瓶相連通；菌種瓶則內置麥粒或堆肥菌種，瓶口以打洞之橡皮塞塞住，孔中放入彎曲之玻璃管，玻璃管一頭和橡皮管連接。經過不同培養時間後取出載玻片，觀察其厚膜孢子發芽情形，外置一組玻璃盒不連接菌種瓶作爲對照之用。又以同樣之設置，將內置堆肥及麥粒之菌種瓶及玻璃盒放置於不同溫度下 (12、16、20、24、28 及 32°C) ，另置對照組不與菌種瓶相連接，放置於相同處理之溫度下，於一定時間內觀察其發芽情形。

四、厚膜孢子接種試驗及腫柄病發生頻度：將厚膜孢子懸浮液 150,000個／20ml 與4公斤覆土混合施用於 0.135m^2 之栽培盆中 ，計4重複，另置一不加厚膜孢子之覆土作爲對照，覆土首先經60°C，24小時後之處理，並按一般洋菇栽培法栽培，並調查其腫柄病發生情形，及其對產量之影響。

結　　果

一、腫柄病菌之培養觀察

將菌絲塊接種於 PDA 培養基平板中 ，約5至7天內可見其瓶狀枝及瓶狀枝孢子，及少部份之厚膜孢子；厚膜孢子與瓶狀枝孢子 (分生孢子) 可同時存在於同一菌落中 ，瓶狀枝孢子大小爲 11~

20×2.5～5μm，通常有一節，且極易發芽，若繼續培養於 24°C 下，則約 10 天後即可見多量之厚膜孢子產生，厚膜孢子大小爲 13～30×16～35μm，厚膜孢子通常由二部份構成，即上方之臘質，具突起及顏色之大型細胞 (cell)，和下方之平滑細胞 (cell) (圖2)。當厚膜孢子脫離菌絲或老化時，下方之細胞則成一空殼而附著於上方細胞；於培養20天後則菌絲開始老化死亡，厚膜孢子大量產生，30 天後菌絲幾乎完全瓦解，僅餘厚膜孢子。

圖 1. 厚膜孢子之發芽試驗 (左，未處理；中，與堆肥菌種相連接；右，與麥粒菌種相連接)。

Fig. 1. Treatments for the germination test of chlamydospore of *M. perniciosa*. (left, non-treated control; middle, connected to a compost spawn; right, connected to a wheat grain spawn of mushroom).

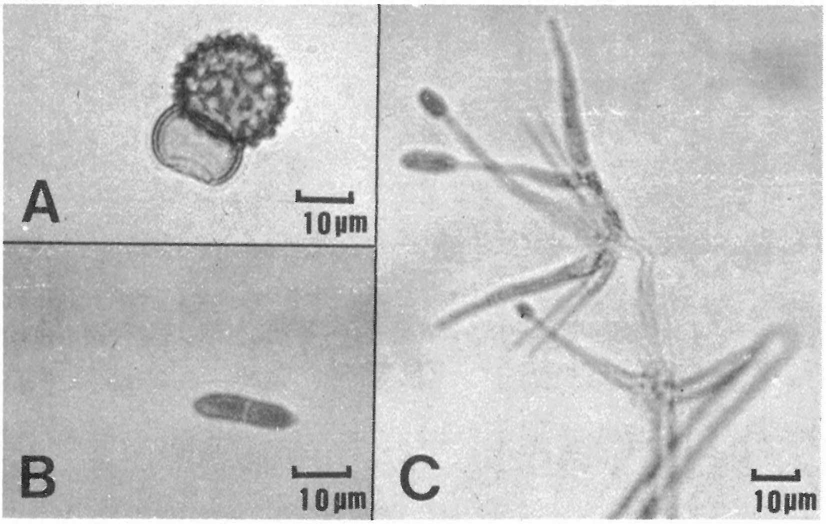

圖 2. *Mycogone perniciosa* 之厚膜孢子 (A)；瓶狀枝孢子 (B) 及瓶狀枝與瓶狀枝孢子 (C)

Fig. 2. *Mycogone perniciosa*: chlamydospore (A); phialospore (B) and phialides with phialospore (C).

二、溫湯處理對厚膜孢子發芽之促進

厚膜孢子懸浮液經 45°C 處理 10 分鐘後，於顯微鏡下染色觀察時，未見有可染色之菌絲段。而不同齡期之厚膜孢子在經過處理培養後經 5 、10、15及 20 天均無法得到發芽之厚膜孢子，這些處理包括不同化學藥品，不同酸鹼度，不同培養基及不同溫度之處理。厚膜孢子在 70°C 下處理時有部份死亡現象 60°C 下處理亦有少數死亡，但 50°C 下處理則未見死亡。

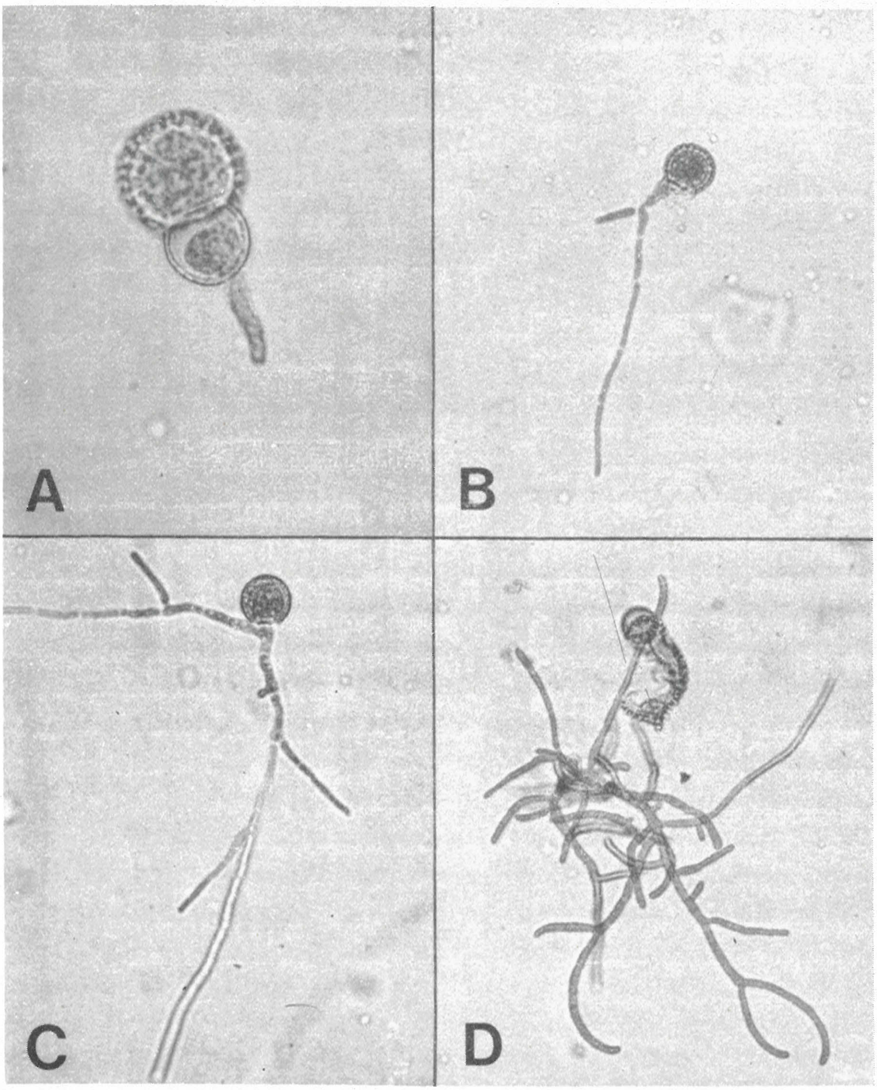

圖 3. 不同培養時期之厚膜孢子其發芽情形（A, 48 小時；B, 64 小時；C, 72 小時；D, 96 小時之培養時間）。

Fig. 3. The germination of chlamydospores of *M. perniciosa*. (A, 48hrs ; B, 64hrs ; C, 72hrs ; D, 96hrs after incubation).

三、洋菇代謝氣體對厚膜孢子發芽之影響

由此種處理方式可得部份厚膜孢子之發芽，即在 water agar 及 PDA 中均可發芽，但在 water agar 中發芽管無法伸長。而連接於堆肥及麥粒菌種中均可發芽， 厚膜孢子之發芽過程如圖 3 所示，首先由厚膜孢子下方之 cell 中伸出發芽管，發芽管有 1 支或 2 支，未見有 3 支以上者。發芽管可迅速

分支或長出一段後再分支，發芽管伸長成爲菌絲而後擴展，最後整個內含物脫離厚膜孢子，而後厚膜孢子剩下一空殼而後瓦解，而不同齡期之厚膜孢子亦有不同的發芽程度，以 3 個月齡爲最適宜發芽，1 個月以下或 6 個月以上較不適宜發芽（表 1）。而由表 1 可知有部分的厚膜孢子會自行死亡，即以 cotton blue 無法加以染色，因此這些死亡之厚膜孢子並不列入發芽率之計算。在不同溫度下培養發現 16～28°C 均適合發芽，而以 24°C 爲最適合，12 及 32°C 下則不發芽，但發芽率仍爲偏低，在 1～14%之間，各不同溫度之發芽率詳列於表 2。

表 1. 不同齡期對厚膜孢子發芽之影響

Table 1. Germination of different ages of chlamydospores of *M. perniciosa* on PDA

齡期（月） Age (month)	死亡數[a] Dead chlamydospore	發芽數[a] Germinated chlamydospore	相對發芽率[a] Percentage of germination (%)
6	70	86	9.2
5	65	99	1.5
4	51	105	11.1
3	31	136	14.1
2	16	74	7.5
1	10	16	1.8

a. 此爲 1,000 個厚膜孢子之觀察結果。

The result of observance on one thousand of chlamydospores.

表 2. 溫度對不同年齡厚膜孢子發芽之影響

Table 2. Effect of temperature on the germination of chlamydospores of *M. perniciosa*

齡期（月） Age (month)	發芽率 (%) Percentage of germination at					
	12°C	16°C	20°C	24°C	28°C	32°C
6	0	0.3	2.1	7.6	4.1	0
5	0	3.4	4.4	9.3	3.3	0
4	0	4.2	5.2	11.4	4.2	0
3	0	8.3	12.2	14.2	8.1	0
2	0	2.0	3.8	6.3	5.8	0
1	0	0.1	1.2	2.0	0.2	0

四、腫柄病在菇床之發生頻度及對產量之影響

接種試驗結果顯示不加厚膜孢子之對照組均未見有腫柄病之病徵，而於接種厚膜孢子之栽培盆中可得到二種病徵型，一爲產生單一個體腫柄而後有褐色滴液出現者，另一爲產生一種 sclerodermoid masses 之聚生腫柄子實體，後者之病徵 Fletcher 氏曾指出其爲普遍存在[11]，而本試驗中發現僅有少數發生。經過不同時期之調查結果詳列於表 3，表中接種天數係以 7 天爲一單位來計算其產量及發生情形。接種後發病的程度佔總個體數的 16 %，佔總產量之 32 %，因此可知腫柄爲害仍爲嚴重且在栽培初期較易發生。由接種試驗結果可推斷腫柄病之發生係自厚膜孢子之發芽後產生感染菌絲再爲害洋菇子實體，厚膜孢子可謂該病發生之第一感染源。

表 3. 腫柄病在菇床上之發生頻度及產生量

Table 3. Incidience and yield of bubbles on bed

接種後天數 Days after inoculation	健全子實體 Healthy sporophores 重量 (g) Wt. (g)	健全子實體 Healthy sporophores 數目 Number	感染子實體 Infected sporophres 腫柄 Stips Wt. (g)	腫柄 Stips No.	聚生 Sclorodermoid mass Wt. (g)	聚生 Sclorodermoid mass No.	百分比 % Wt.(g)	百分比 % No.
20	124	12	38	3	0	0	24	20
27	382	35	66	4	176	3	39	17
34	71	8	88	5	0	0	55	38
41	306	27	62	3	0	0	17	10
48	46	7	19	2	60	2	63	36
55	142	16	35	1	0	0	20	6
62	138	17	17	1	0	0	11	6
total	1,209	122	325	19	236	5	32	16
not incoulated	1,837	198	0	0	0	0	0	0

討　　論

由本試驗知，厚膜孢子的發芽和氣體有密切的關係存在，且厚膜孢子的齡期 (age) 亦爲一重要的因素，當 chlamydospore 太年輕或太老時其發芽率均不高，2～4 個月爲最適合發芽之時期。至於何種氣體或何種氣體比例濃度下才會促使其發芽，及爲何 3 個月齡之厚膜孢子其發芽率最高，必須作進一步試驗才可獲知。厚膜孢子發芽後如何擴展及其與洋菇菌絲間的關係如何均是未來工作之方向，如能對這些問題加以瞭解，則有助於未來的防治工作。在整個試驗過程中得知，最適合發芽之條件爲選取 3 個月齡之厚膜孢子置於洋菇菌絲呼吸之氣體下，於 24°C 下培養，經 2～4 天取出觀察即可見厚膜孢子之發芽現象，但亦曾發現對照組之厚膜孢子並未在氣體刺激下，仍有極少部分之發芽現象，此點有待進一步的證明。而從發芽管伸出到整個厚膜孢子外殼脫落過程所需時間爲培養 36 至 96 小時後，且各厚膜孢子所需時間差異不大。在 *Mycogone perniciosa* 之可能有性世代 *Histoplasma capsulatum* 其 macroconidia 之發芽條件爲 30°C，pH 在 6.5～8.0 之間，濕度 100 %，而且在 cystine-dextrose blood agar 下才適於其發芽 (15)，其發芽條件和本試驗之厚膜孢子發芽方式不同。在接種試驗時，厚膜孢子與覆土混合並調整其含水量在 30 %，放置於室內一天後再進行接種，於第 20 天開始即出現可見之病徵，且有二種病徵型出現，而據 Fletcher 氏等指出由侵入到病徵出現所需的時間爲 7～13 天 (11)， 因此可知厚膜孢子混合於覆土後，在極短時間內即可發芽蔓延，而腫柄病在第二週期後發現罹病情形較少、其原因可能爲厚膜孢子須經一段時間之休眠，而短時間內無法作第二次感染。在對照組中，不加入厚膜孢子則無法產生病徵，由此可知厚膜孢子爲病害發生之第一感染源，而腫柄病之殘存亦以厚膜孢子方式來存在於土壤中。因此可知 *M. perniciosa* 之發芽條件較爲特殊，而厚膜孢子的發芽過程中，發芽管由下方之細胞中伸出，且發芽管由同一部位伸出一支以上，是否在同一部位具有許多發芽孔或同一發芽孔同時伸出二支發芽管，此點須作電子顯微鏡之觀察來作進一步證明。

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The chlamydospore germination of *Mycogone perniciosa* and its effect on the occurrence of wet bubble of mushroom on the bed[1]

Ying-ming Liao[2]

Summary

Chlamydospores of *Mycogone perniciosa*, the causal organism of wet bubble of mushroom, did not germinate on different media in the laboratory, not even treated with heat (40 to 70°C), chemicals and/or organic solvents. However, the germination was observed on potato dextrose agar connected to the gas produced by the mycelia of mushroom in compost 36 hours at 24°C. The maximum percentage of germination, i. e. 14%, was recorded 48 hours at 24°C on 3-month-old chlamydospores. No germination was observed when the temperature was lower than 12 or higher than 32°C. One or two germ tubes were produced from the low cell of chlamydospore. Ninety-six hours after incubation, the cell content of chlamydospore completely moved into the germ tubes leaving an empty cell. When chlamydospores were incorported into the casing soil on the bed, bubble mushroom which is the typical symptom were produced. Therefore, the germination of the chlamydospore of *M. perniciosa* may be, in part, stimulated by the gas produced by the mycelia of mushroom and/or the complex of the mycelia and the growth media.

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